CORRELATION BETWEEN MODIFIED MALLAMPATI TONGUE SCORE WITH VARIATION IN CRANIOFACIAL POSTURE & MORPHOLOGY IN A LATERAL CEPHALOGRAM

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ABSTRACT

Introduction: The Modified Mallampati Tongue Score (MMT) is commonly used in anesthesiology for the pre-anesthetic assessment of the airway in patients. This score roughly estimates the size and position of the tongue relative to the oral cavity, with higher scores associated with difficult intubation and increased incidence of breathing interferences, such as obstructive sleep apnea. The distance from the tongue base to roof of the mouth decreases from MMT-I to MMT-IV. The tongue shape and position impact the airway patency in the hypopharynx, contributing to changes in craniofacial head posture followed by changes in craniofacial morphology. This present study examines the pattern of associations between the Modified Mallampati Tongue Score positions and 1) the postural relationship of the cranium, hyoid bone, cervical column, and tongue 2) size, shape, and position of the craniofacial components, as depicted in a lateral cephalogram.

Methods: This retrospective study was performed on 200 subjects (145 female, 55 male) prior to starting orthodontic treatment. MMT was assessed from one photograph of maximum mouth opening and tongue protrusion. Pretreatment cephalograms were analyzed to evaluate craniocervical posture, resting tongue position, hyoid bone position, or sagittal and vertical skeletal relationships. MMT (I-IV) was also compared to basic demographics (age, gender, race/ethnicity). One-way ANOVA, Chi-square test, and correlation analysis were used for statistical analysis. Probability values <0.05 were accepted as significant.

Results: A total of 200 patients (72.5% Female, 27.5% Male, 54% African American), with a mean age of 20 (Range 7-73), were included for the study. MMT-III was most prevalent (34%). MMT was not associated with age, gender, or race/ethnicity. Mean cephalometric measurements of hyoid position (p=0.06-0.03), mandibular position (p=0.006), ANB (p=0.009), and SNB (p=0.023, were shown to have significant differences with MMT. MMT positively correlated with the ANB (p=0.001), Wits (p=0.016), vertical position of the hyoid bone to neck (p=0.004) and mandible (p=0.048); and inversely correlated with the SNB (p=0.003) and Pog:Na-Perp (p=0.045).

Conclusion: A higher MMT correlates to a Class II skeletal morphology and extended craniofacial posture. Preliminary results suggest high tongue position influences Class II craniofacial morphology, enhancing maxillary prognathic growth and mandibular deficiency. This indicates that MMT can be a potential predictor of craniofacial growth patterns, strengthening the prognosis and long-term stability of orthodontic treatment.

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CHAPTER 1

INTRODUCTION

The tongue is one of the most versatile muscles in the human body. Being the largest organ in the oral cavity, its function, posture, size, and shape have a role in the positioning of dentoalveolar structures (Peat, 1968) and associations with maxillary and mandibular morphology (Primozic et al., 2013). However, there is a lot of controversy as to whether the tongue adapts to existing oral morphology, or actively molds its surrounding tissues (Ingervall et al., 1990; Frohlich et al., 1993; and Frohlich et al., 1997). The Melvin Moss functional matrix theory states that soft tissue function will dictate how the hard tissues form - "form follows function" (Moss, 1997). The tongue shape and position impact the airway patency in the hypopharynx (Yucel et al., 2005) which contributes to changes in head posture, particularly in patients with breathing disorders, such as obstructive sleep apnea (Piccin et al, 2015). In other abnormal breathing patterns, such as in mouth breathing, reduced airway space leads to postural adaptations at the level of the oropharynx - with a lower tongue posture and hyoid bone in relation to the mandible, which may cause changes in the mandibular resting position and head extension (Ballard, 1951; and Tourné, 1991). There is a causal relationship between the mode of breathing, tongue position, and craniofacial posture. Prolonged low tongue positions, lower mandibular posture, and extended head posture during growth may cause the dentoalveolar complex and mandible to adapt to this changed position resulting in variations in craniofacial morphology (Harvold, 1973). With tongue volume integrated functionally with tongue position (Enlow, 1982), multiple clinical studies have claimed to correlate tongue volume with various morphological factors such as mandibular arch size and posture (Vig and Cohen 1974; Tamari et al., 1991), dentition position (Lowe et al., 1985; Cohen et al., 1976); Vig and Cohen, 1974) maxillary expansion (Enlow 1982), vertical facial height (Doual-Bisser et al., 1989) and combined horizontal and vertical location of chin and symphysis (Yoo et al., 1996). However, no study has used direct measures to describe tongue volume or position.

The Modified Mallampati Tongue Score (MMT) is reported to be a simple, reproducible, and reliable method for pre-anaesthetic airway assessment in the world of anesthesiology (Mallampati et al., 1985). MMT provides a structured, rough estimate of the tongue size and position relative to the oral cavity. A higher MMT score is associated with difficult intubation and a higher incidence of obstructive sleep apnea (OSA) in various age & ethnic groups (Nuckton et al., 2006; Santos et al., 2011; and Lam et al., 2005). Increasing overlap in airway and craniofacial & orthodontic research has uncovered a dynamic relationship between airway patency (as depicted by tongue position and oropharyngeal structures (Gurani et al., 2019)), craniofacial posture, and craniofacial morphology. Numerous cephalometric studies have correlated tongue posture, craniofacial posture and morphology to the severity of OSA (Gungor et al., 2013; Francesco et al., 2011; and Silva et al., 2013) and other abnormal breathing patterns (Ucar et al., 2012; Chaves et al., 2012). However, there is limited research on the effects of different tongue positions on craniofacial growth. The interaction between the tongue and craniofacial skeletal development is essential for understanding the mechanism of specific types of malocclusion and objectively measures outcomes of various surgical/or orthodontic treatments. The simplicity, reproducibility, and efficacy of the Modified Mallampati Score on airway assessment leads us to hypothesize a relationship exists between this score and variations in craniofacial posture and craniofacial morphology.

The aim of this present study is to examine the pattern of associations between the Modified Mallampati Score and 1) the postural relationship of the cranium, hyoid bone, cervical column, and tongue, and 2) the size, shape and position of the craniofacial components, as depicted in a lateral cephalogram.

CHAPTER 2

REVIEW OF THE LITERATURE

2.1 Mallampati Tongue Score

The Mallampati classification was first described in 1985 as a method to predict the ease or difficulty of orotracheal intubation in clinical practice (Mallampati, 1985). This method was modified by Samsoon and Young to include four categories in 1987 (Samsoon and Young, 1987). This score roughly estimates the size and position of the tongue relative to the oral cavity. It is an assessment of the oropharyngeal view, based on the extent of exposure of the glottis when the tongue base is disproportionately large and predicts difficult tracheal intubation and laryngoscope insertion. The airway is classified according to the structures seen as follows: Class I - soft palate, fauces, uvula, pillars; Class II - soft palate, fauces, major part of the uvula; Class III - soft palate, base of uvula; Class IV - soft palate not visible at all (Figure 1) (Samsoon and Young, 1987).

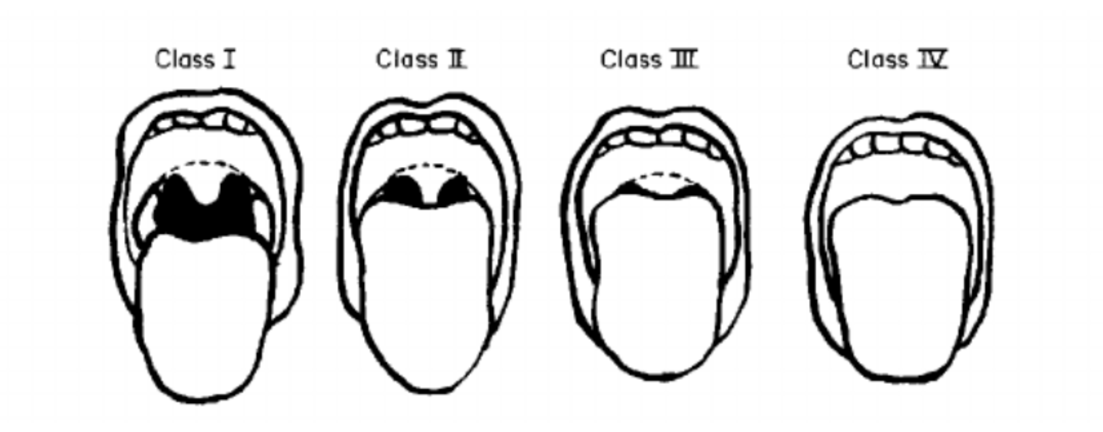

Figure 1: Modified Mallampati Tongue Score (Samsoon and Young, 1987)

Mallampati Scoring Technique The original paper of Mallampati in 1985 (Mallampati, 1985) demonstrated patient positioning for the Mallampati Score assessment by having the patient sit upright with their head in a neutral position, and having them open their mouth as widely as possible and protrude their tongue to a maximum, without phonation (Mallampati, 1985). Whether the patient should phonate during this test was subsequently observed to affect the classification due to the unpredictable motion of the pharynx, potentially obstructing the view (Oates, 1990; Wilson, 1990). However there is an array of contradictory findings that suggest phonation improved reproducibility and the oropharyngeal outlook (Amadsun, 2010; Lewis, 1994), but there was still debate on whether there was accurate correlation of the Mallampati score with phonation to the laryngoscopic view used to assess difficult intubation (Amadsun, 2010).

When evaluating patient positioning, (Tham, 1992), reported the supine posture to produce a slight, systematic, non-significant worsening of the Mallampati score. A systematic review by (Lee, 2006) showed that the included studies did not specifically document the position of the patient during the Mallampati test, limiting the ability to dictate the effect of supine position on the Mallampati assessment. However, it can be deduced that the sitting position was generally more predictive and took less time and effort for the patient to produce a non-varying result (Lewis, 1994). Although Manabe in 2014 (Manabe, 2014) reported a neutral tongue position to be superior to tongue protrusion in the accuracy of the Mallampati test as predictor of difficult intubation, Ouchi (Ouchi, 2020) reported that tongue protraction was associated with decreasing the score of the Mallampati test.

Mallampati Score and Sleep-disordered breathing A higher Mallampati score is associated with a smaller oral airway. A number of studies (Liistro, 2003; Rodrigues, 2010; Kim, 2013) have reported a combination of a high Mallampati score and nasal obstruction to be risk factors for sleep-disordered breathing, including obstructive sleep apnea (OSA). Nuckton (Nuckton, 2006) found for every 1-point increase in Mallampati score, the odds of having OSA increase more than 2-fold, independent of other variables such as history of snoring, overjet, tonsil size, neck circumference, and body mass index. It was inferred that when the base of the tongue is disproportionately large, or the oropharyngeal cavity is disproportionately small, the tongue masks the visibility of the faucial pillars and uvula (Mallampati, 1985), which increased the risk of OSA - thereby indicating the Mallampati score to be an independent predictor of OSA.

Prevalence of Mallampati Score Sleep-disorder breathing research has revealed many anthropometric and demographic variables associated with increased risk of OSA. This has led to research associating these factors to the Mallampati score. Menon et al in 2017 found a positive correlation with increased neck circumference and higher BMI (Menon, 2017). This is similar to the findings of Lam (Lam, 2005) who additionally found that Asians had a higher Mallampati Score, larger thyromental angles, shorter thyromental distances, and more severe OSA than white subjects. A higher Mallampati score (III/IV) was found to have significant correlation with OSA in African Americans, but not in Caucasians, and was implicated to be used in the physical examination of African American patients with suspected sleep-disorder breathing (Albustami, 2011). The Mallampati score has been found to be strong predictor of difficult intubation in adult patients of both genders (Uribe, 2015). With regard to age, patients categorized as having Class III and IV Mallampati Score tended to be older in age (Ouchi, 2020; Moon, 2013).

Mallampati Score and Tongue Position Although Mallampati in 1983 (Mallampati, 1983) associated the tongue size and pharyngeal dimensions with difficult intubation, Skolimowski in 1975 (Skolimowski, 1975) reported failed intubation in a micrognathic patient due to a reduced anteroposterior dimension of the pharynx with a low posterior tongue posture. This implicates the involvement of tongue posture along with tongue size in this method of assessment.

2.2 Tongue Size and Posture

The tongue is the most agile and versatile muscular organ in the body. It is centrally located in the oral cavity and has no skeletal bony base. Most of the growth of the tongue is completed before the age of 16 (Bell, 1970). The tongue size, posture, function, have been considered to be one of the main molding forces within the oral environment (Peat, 1968). The concept of equilibrium of the labio-lingual muscular forces in maintaining the stability of the arch shape and position of teeth has been recognized by many orthodontists (Baker, 1984). The magnitude of muscular forces exerted by the tongue in function and at rest were higher compared to lips and cheeks (Proffit, 1978). Brodie (1953) stated that the final position of the teeth and alveolar structures is determined by the muscular forces that surround them. Cohen and Vig (1976) found that tongue size and position are functionally integrated and noticed that the increase in relative tongue size is harmonious with the descent of the tongue, and the two changes together maintain function during growth.

Tongue size/volume differences range from 15-29% in the average population (Bandy, 1969; Oliver, 1986; Lauder, 1991, Yoo, 1957). Tongue volume was positively correlated to lower arch size, and more in males (Tamari et al, 1991). Other studies have reported the effect of tongue size on mandibular posture (Cohen and Vig, 1974), dentition position (Lowe, 1985; Vig and Cohen, 1974; Cohen and Vig, 1976), and maxillary expansion (Enlow, 1982).

On the other hand, tongue posture was found to be associated with a sagittal and vertical jaw relationships (Primozic, 2013; Yoo, 1996; Farheen, 2019; Subrahmanya, 2014). Graber (1958) believed muscle posture to be more important than muscle function in molding the hard tissues and proposed the method to assess tongue posture on a lateral cephalogram. The resting tongue posture of skeletal Class II patients was found to be higher as compared to Class I and Class III (Farheen, 2019) and a lowered tongue posture was most posterior in skeletal Class III subjects (Farheen, 2019; Primozic, 2013).

The tongue shape and posture impact the airway patency in the hypopharynx (Yucel, 2005). The genioglossus muscle, which forms most of the tongue mass (Baker, 1954), plays a vital role in maintaining the upper airway patency by increasing the antero-posterior dimension at the level of the oropharynx (Kobayashi, 1996). The hyoid bone is suggested to be the skeleton of the tongue and is attached by musculature to the chin, which is the chief base for function of the tongue. (Sicher, 1960). It is an integral part of the postural apparatus of the head and jaws. In abnormal breathing patterns, such as chronic mouth breathing and obstructive sleep apnea, a reduced airway space leads to postural adaptations at the level of the oropharynx - with a lower tongue posture and hyoid bone in relation to the mandible, which may cause a lower mandibular resting position and head extension (Ballard, 1951; Tourné, 1991). OSA subjects show both anatomical and physiological differences in their airways composted to normal individuals. A subject with OSA who is awake is able to maintain an upright tongue posture protects them from upper airway collapse when moving from an upright to supine position (Miyamoto, 1997), reiterating the effect of tongue posture on airway patency. Increased tongue volume also upper airway anatomy making it one of the causing factors of obstructive sleep apnea (Arya, 2010).

2.3 Functional Matrix Theory

The functional matrix hypothesis was developed by Melvin Moss. This theory claims "that the size, shape, location, and structural integrity of every skeletal unit is always secondary to temporally primary changes in their specific functional matrices" (Moss, 1969). In other words, soft tissues function will dictate how the hard tissues form - "form follows function".

The head is a region within which particular functions are entirely carried out by a functional cranial component: 1) functional matrix - which carries out the function and 2) skeletal unit - which protects andpports its specific functional matrix. The skeletal unit may be composed of bone, cartilage, or tendinous tissues. Both maxilla and mandible are formed from a number of microskeletal units. There are two types of functional matrices that are indicative of their site of activity: periosteal and capsular (Moss, 1969). The periosteal matrix corresponds to the immediate local environment -- muscles, blood vessels, nerves, glands, teeth etc. -- which causes direct growth of the microskeletal units. The effect on the size/shape of the skeletal unit is by osseous deposition and resorption (Moss, 1969).

The capsular matrix is defined as capsules that contain a series of functional cranial components (skeletal units and their functional matrices). Capsular matrices act indirectly on the macroskeletal units and are carried outward in a passive manner. The location in space of the skeletal unit is changed, not by osseous deposition and resorption. There are two cranial capsules which are the neurocranial and orofacial capsules. The orofacial capsule is covered by skin and mucosa and contains the oronasopharyngeal functioning spaces. These spaces are said to have regions that have a primary function of maintaining a patent airway (Moss, 1969). This is accomplished by a dynamic musculoskeletal postural balance which is termed the "airway-maintenance mechanism". Bosma (1963), believed that the development of head and neck posture is about this pharyngeal airway, as the airway is maintained throughout the range of motion of the head and neck. Postnatal development of the tongue is also integrally related to the acquisition of an open masticatory cavity. As the performance area expands, the tongue elongates anteriorly and has greater mobility (Moss, 1969).

Clinically, etiology of malocclusion can occur due to deficient functioning (orofacial capsular matrix) such as mouth breathing, digit sucking etc. Myofunctional appliances, such as the Frankel appliance, restricts the pressure of the buccinator and labial forces, allowing outward expansion of the teeth and jaws, facilitated by lingual forces of the tongue (Frankel, 1989). It has also been claimed that the tongue growth and size influence the midfacial control mechanism, which determines the growth of surrounding orofacial elements. (Moss, 1971). Craniofacial morphology (skeletal units) can be said to follow function (from the functional matrices).

2.4 Head Posture and Craniofacial Morphogenesis

Head posture is a dynamic concept and plays a role in craniofacial development. Solow and Tallgren (1976) found that the position of the head in relation to the cervical spine showed a comprehensive relationship to craniofacial morphology than the position of the head in relation to the true vertical. Extension of head in relation to the cervical column was found in connection with large anterior and small posterior facial heights, small antero-posterior cranio-facial dimensions, large inclination of the mandible to the anterior cranial base and to the nasal plane, facial retrognathism, a large cranial base angle, and a small bony nasopharyngeal space (Solow and Tallgren, 1976). However, morphology can also influence head posture. Morphological deviations that affect adequacy of airways can cause the head to maintain an extended head posture to maintain adequate naso-oro-pharyngeal airways (Bosma, 1963). For example, bicondylar dysplasia which restricts forward growth of the mandible can place the tongue too posteriorly. This prolonged extended head posture can result in increased anterior facial height, beaked nose, and antegonial notching.

Solow and Kreiborg (1977) proposed the soft tissue stretching hypothesis to describe the relationship between craniofacial changes and postural development. For example, this hypothesis was responsible for the development of notching in the gonial region in patients with prolonged extended head posture. They stated that during marked extension of the head, the downward traction of the investing fascia of the neck -- which is firmly attached to pterygomasseteric sling in the gonial region -- results in gonial apposition. In normal craniofacial development, a balance between the upward traction of pterygomasseteric sling and downward tracking of the investing fascia of the neck will cause remodeling with resorption of the gonial region (Bjork and Skieller, 1972).

In contrast to the Moss functional matrix theory (Moss, 1976), Solow in 1992 (Solow, 1992) used the cybernetic model (Petrovic, 1972) describing the influence of functional factors on facial development -- the soft tissue stretching model (Solow and Kreiborg, 1977) to associate the craniocervical angle (head posture) with facial development. They found a relationship between craniocervical angulation and development of the lower face: children with large craniocervical angle (extension) and an un upright position of the upper cervical column displayed a more vertical subsequent facial growth pattern than children with a small craniocervical angulation (flexion) and a backward inclination of the upper cervical column (Solow, 1992). This was attributed to the soft tissue stretching hypothesis (Solow and Kreiborg, 1977), which reasoned that obstruction of upper airways lead to an increase in craniocervical angle to facilitate respiration. This would lead to stretching of the soft tissue layer covering the face and throat, and the backward and downward components of the strain in the soft tissue layer restricts or redirects the forward component of facial development in a more caudal direction. This study showed that posture seemed to influence rather than predict craniofacial growth, as it was one of many factors that influence facial development. But extreme craniocervical angles in a child were able to be of some prognostic value regarding facial developmental trends (Solow and Kreiborg, 1977).

Natural head position is the upright position of the head via the balancing of the cervical spine and muscle groups. Variations in natural head position have been observed, ranging between extension and flexion. These variations were an adaptive role in terms of respiration (Solow and Tallgren, 1976). Numerous studies have reported subjects with OSA to have an extended natural head posture, reduced posterior airway space, an abnormally long soft palate, and a low position of the hyoid bone (Wong, 2005; Pracharktam, 1996; Solow, 1993). Additionally, the more severe the OSA, the more extended the natural head position as indicated by an increase in craniocervical angles (Sokucu, 2016).

2.5 Cephalometric Analysis of Resting Posture of the Head, Neck, Hyoid bone, Tongue

Upper airway patency is a result of many interrelated anatomic and physiologic factors. Recurrent upper airway obstruction during sleep causes obstructive sleep apnea (OSA). In addition to pharyngeal size and tissue compliance, conditions such upper airway tumors (Zorick, 1980), adenotonsillar hypertrophy (Orr, 1981), and conditions associated with macroglossia (Mezon, 1980), reduce airway dimensions and cause OSA. Tonsillar and adenoid enlargement are considered the most common contributors of upper airway obstruction in young children (Greenfeld, 2003). The obstruction reduces the depth of the oropharynx, leading to lowered posturing of the hyoid bone, which forces the tongue anteriorly and causes compensatory change in the child's mode of breathing, increasing the incidence of OSA. (Adamidis, 1983; Subtelny, 1980).

Upper airway obstruction and altered breathing pattern may potentially affect the child's dentofacial growth (Subtelny, 1980; McNamara, 1981) but in reverse, airway size is also affected by craniofacial morphology as seen in OSA patients with severe retrognathia (McNamara, 1981). With increasing research on OSA, traditional cephalometry has been used extensively to quantify specific airway parameters (Guilleminault, 1984; Linder-Aronson, 1970; Solow, 1984). Lowe (Lowe, 1986) investigated the relationship among craniofacial, airway, tongue, and hyoid variables obtained from lateral cephalometric radiographs in adult male subjects with OSA. In addition to the conventional cephalometric analysis, they determined seven linear measurements in the airway, tongue, and hyoid areas. The study demonstrated an interaction between craniofacial morphology and pharyngeal soft tissues. Patients with OSA had several atypical craniofacial structures that reduced the upper airway dimensions and stability (Lowe, 1986).

The hyoid bone plays an important part in cranial balance and posture. It facilitates maintaining an airway, swallowing, and preventing regurgitation, and maintaining the upright postural position of the head. There was a lot of controversy over whether the hyoid bone position could be precisely measured by cephalometric means, particularly with variations in head posture. Bibby in 1979 (Bibby, 1979), introduced the analysis of hyoid bone position called the hyoid triangle. The hyoid triangle allowed assessment of the hyoid bone in three directions and is not dependent on the cranial reference plane, minimizing the effect of changes in head posture. This study proposed standard values for the dimensions of the hyoid triangle. These cephalometric points and planes can be used to assess the functional importance of changes in hyoid position (Bibby, 1981).

2.6 Limitations of Past Studies

Despite the number of studies done to evaluate the effect tongue size and posture, no direct measures have been defined to describe tongue position and volume. With the tongue encased within the oral cavity, obtaining its real measurements within the oral cavity is difficult. Various techniques have been developed for evaluating the tongue's size in vivo -- impression techniques (Tamari, 1991), direct tongue measurements (Oliver, 1986), fluid displacement method -- but have failed to measure the interior portion of the tongue. Furthermore, different imaging techniques have been introduced to assess the tongue volume and posture: cephalometrics (Cuccia, 2007), computed tomography (CT) (Roehm, 1982), cone-beam computed tomography (CB-CT) (Uysal, 2013) and magnetic resonance imaging (MRI) (Iida-Kondo, 2006). However, these techniques have different disadvantages.

In addition to this, with the hyoid bone and head posture affecting tongue posture and relative tongue volume, no studies have included these variables when evaluating tongue size and position and its implications with airway patency and development of craniofacial morphology.

CHAPTER 3

AIMS OF THE INVESTIGATION

Specific Aims:

The aim of this present study is to investigate if a relationship exists between the Modified Mallampati Tongue Score and variations in craniofacial posture and morphology as depicted in a lateral cephalogram. Specific aims are:

- To determine if the different Modified Mallampati Tongue Score positions correlate to variations in the postural position of the tongue, hyoid bone, cervical spine, and cranium, as depicted in a lateral cephalogram
- To determine if the Modified Mallampati Tongue Scores correlate to variations in size, shape, and position of the craniofacial components (maxilla & mandible), as depicted in a lateral cephalogram.
- To determine the prevalence of the various Modified Mallampati Tongue Scores in specific patient demographics such as age, gender, race, and ethnicity.

Our null hypothesis is that there will be no statistically significant relationship between the different Modified Mallampati Scores tongue positions and 1) variations in craniofacial head posture 2) variations in craniofacial morphology, as depicted in a lateral cephalogram.

Significance:

If a statistically significant relationship is found between the Modified Mallampati Tongue Score and variations in craniofacial posture and morphology, the orthodontic implications of this form of assessment in diagnosis and treatment planning are profound. The Modified Mallampati Score can be a potential predictor of craniofacial growth patterns, enhancing the prognosis and long-term stability of orthodontic treatment.

CHAPTER 4

MATERIALS AND METHODS

200 subjects who have undergone routine screening and record taking in the Department of Orthodontics at Temple University Kornberg School of Dentistry (TUKSoD) Screening Clinic between June 2020 to Nov 2020 were selected for this retrospective study. Patient data including age, gender, race & ethnicity was recorded. Due to the retrospective nature of this study and inability to obtain consent from the subjects enrolled in this study and the usage of their PHI (protected health information) for research purposes, a HIPAA waiver and approval of this study was obtained by the university's institutional review board in February 2021 (Appendix A).

Inclusion criteria included patients ranging in age 7-80 years, with mixed and permanent dentition, diagnosed as needing orthodontic therapy, no history of prior orthodontic treatment, with diagnostic lateral cephalograms in which the tongue and hyoid bone are clearly visible, and intraoral tongue photos where the Modified Mallampati Score is illustratable. Exclusion criteria consisted of subjects with limited mouth opening, edentulous patients, dental abnormalities, and subjects with limited movement in their temporomandibular joint.

4.1 Modified Mallampati Tongue Scoring

The Modified Mallampati Tongue Score was obtained during the clinical examination of each subject. The patient was asked to sit upright with their head in neutral position, open their mouth as widely as possible and to protrude their tongue to a maximum. The patient was instructed to not emit sounds during the assessment (Samsoon and Young, 1987). A digital intraoral photograph was taken of this tongue position and stored in the Dolphin Imaging (Patterson Dental Supply, Inc) software program. The assessment of MMT was done twice. The first assessment of scores was evaluated by a single orthodontic resident during initial data collection. The second round of MMT scoring was re-assessed in one sitting by the same orthodontic resident and subjects without consistent scores between the two assessments were excluded from the study. The Modified Mallampati I to IV grading system was used (Figure 2) (Samsoon and Young, 1987).

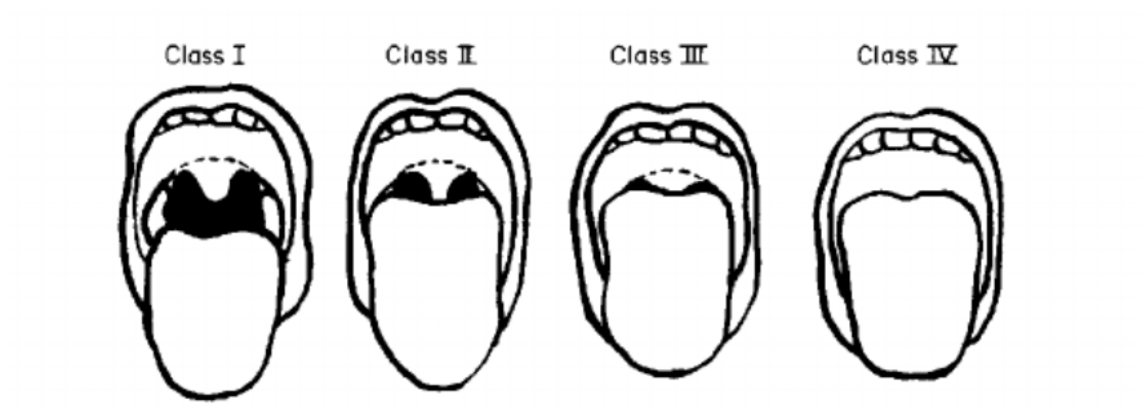

Figure 2: The Pictorial Classification of the Pharyngeal Structures as seen when Assessing the Tongue Position According to the Modified Mallampati Classification. Structures seen: Class I - soft palate, fauces, uvula, pillars; Class II - soft palate, fauces, major part of the uvula; Class III - soft palate, base of uvula; Class IV - soft palate not visible at all (Samsoon and Young, 1987)

4.2 Cephalometric Measurements & Analysis

All subjects underwent a right lateral cephalogram of the skull and cervical spine in normal standing position for cephalometric evaluation. To reproduce the subject's natural head position, the subjects were asked to stand and stare at their face in a mirror located in front of their head approximately 4-5 feet away (Moorrees and Kean, 1958). A single trained examiner performed two cephalometric analyses on the radiographs through computerized methods.

The first cephalometric analysis described the resting tonicity of skeletal muscles relative to skeletal and soft tissue elements in the oral pharyngeal areas by assesing the resting posture of the cranium, cervical spine, hyoid bone, and tongue. This assessment was done using an amalgamation of analyses created for this study (Solow and Tallgren, 1976; Bibby et al., 1981; and Lowe et al., 1986). Figure 3 represents the measurements, anatomical landmarks and constructed lines used in the analysis. The cephalometric analysis was done on the Amira Software (Thermo Fisher Scientific) (Appendix B).

The second cephalometric analysis determined differential hard and soft tissue morphology stratified against sagittal and vertical skeletal relationships and was analyzed in Dolphin Imaging Software (Patterson Dental Supply, Inc) using the following methods of analyses:

1) Steiner analysis: This analysis uses the anterior cranial base (S-N) rather than Frankfort Horizontal as a reference line. Using angular measurements SNA, SNB, and ANB, it allows for assessment of sagittal positioning of the maxilla and mandible in relation to the anterior cranial base and in relation to one another (Steiner, 1953).

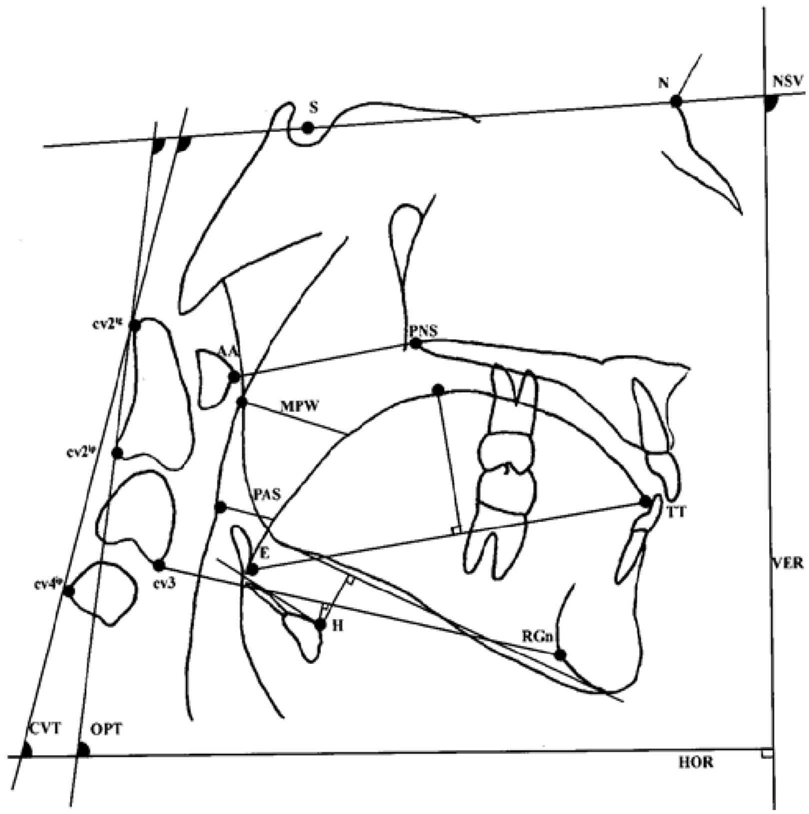

Figure 3: The Cephalometric Landmarks and Analysis describing the Resting Tonicity of Skeletal Muscles Relative to Skeletal and Soft Tissue Elements in the Oral-Pharyngeal Areas. (Solow and Tallgren, 1976; Bibby et al., 1981; and Lowe et al., 1986). Legend Below:

ANATOMICAL LANDMARKS

S	Sella - the anatomical center of the pituitary fossa.
N	Nasion – the most anterior point on the frontal suture located in the midsagittal plane.
PNS	Posterior nasal spine – the most posterior point on the hard palate.
AA	Atlas - Most anterior point on the atlas vertebrae.
cv2	the tangent point of OPT on the odontoid process of the second cervical vertebrae.
cv2	the most posterior, inferior point on the corpus of the second cervical vertebrae.
cv3	the most anterior, inferior point on the third cervical vertebrae.
cv4	the most posterior, inferior point on the corpus of the fourth cervical vertebrae.

E	Epiglottis – the most inferior anterior point on the epiglottis.
H	Hyoidale – most anterior, superior point on the body of the hyoid bone.
PAS	Posterior pharyngeal airway space – distance between the tongue and posterior pharyngeal wall (constructed from a line drawn from B point through gonion).
MPW	Middle pharyngeal width – distance between tongue and the middle pharyngeal wall (constructed from a line drawn from the mandibular incisor tip and occlusal surface of the first mandibular molar.
RGn	Retrognathon – the most posterior, inferior point on the mandibular symphysis.
TT	Tongue tip

CEPHALOMETRIC MEASUREMENTS

Linear Measurements	
tongue length	distance between TT and E.
tongue height	the distance between the dorsal height of contour of the tongue and the perpendicular line drawn to the TT-E line.
vertical position of hyoid to the mandible	distance between H and perpendicular line drawn to the mandibular plane angle.
vertical position of hyoid to the neck	distance between H and perpendicular line drawn to the RGn – cv3 line.
Angular Measurements	
OPT – HOR	angle between OPT line (tangent line to the posterior of the second cervical vertebrae) and the true horizontal line.
CVT – HOR	angle between the CVT line (tangent line to the posterior of the second and fourth cervical vertebrae) and true horizontal.
OPT – SN	angle between the OPT line and the SN line.
CVT – SN	angle between the CVT line and the SN line.
SN – VER	angle between the SN line and the vertical standardization line (VER).
hyoid plane angle	the superior, posterior angle formed by the intersection of the hyoid plane (line drawn tangent to the greater wing of the hyoid bone) with the C3-RGn line.

2) Wits analysis: The Wits appraisal of jaw disharmony uses perpendicular lines drawn from A point on the maxilla and B point on the mandible to the occlusal plane, drawn through the area of overlap of the premolars and first molars, to assess the relationship of the jaws to one another. This method eliminates the effects of anteroposterior positioning of the jaws and rotational effect of the jaws in relation to the cranial base as seen in the Steiner analysis (Jacobsen, 1975).

3) McNamara analysis: The McNamara analysis was used to support the other two analyses in their description of the sagittal position of the jaws. This analysis uses a milletric measurement from A and B point to nasion perpendicular to relate jaw position (McNamara, 1984).

4) Jarabak Analysis: This analysis uses the ratio between the posterior facial height (S-Go) to anterior face height (N-Me) to assess the vertical facial patterns as hyperdivergent, normodivergent, and hypodivergent (Siriwat and Jarabak, 1985).

4.3 Statistical Analysis

One-way ANOVA analysis was used to identify the association of Mallampati Scores I-IV with the mean and standard deviations of the linear (Figure 2: 4-7) and angular measurements (Figure 2: 1-6) from the first cephalometric analysis that describes the resting tonicity of skeletal muscles relative to skeletal and soft tissue elements in the oral-pharyngeal areas (Figure 2). To further evaluate, a post-hoc t-test was done to compare the cephalometric measurements with each MMT.

One-way ANOVA analysis was used to associate the Mallampati Scores I-IV with the mean and standard deviations from the Steiner, Wit's, McNamara, and Jarabak analysis in the second cephalometric analysis that determines the differential hard and soft tissue morphology that is stratified against sagittal and vertical skeletal relationships. To further evaluate, a post-hoc t-test was done to compare the cephalometric measurements with each MMT.

Pearson's correlation index was used to correlate and determine if a linear relationship exists between the Mallampati Scores I-IV with the measurements of the first and second cephalometric analysis. Pearson's correlation index was also used to correlate and determine if a linear relationship exists between the measurements of first cephalometric analysis (that describes the resting tonicity of skeletal muscles relative to skeletal and soft tissue elements in the oral-pharyngeal areas) and the second cephalometric analysis (that determines the differential hard and soft tissue morphology that is stratified against sagittal and vertical skeletal relationships).

A Chi square test was used to determine the relationship between the age, gender, 3 racial groups (African American, Caucasian, Asian) and 1 ethnic group (Hispanic) with the Mallampati Scores I-IV.

Probability values <0.05 were accepted as significant.

For reliability testing, 10% of the variables were randomly selected and re-measured. Intrarater and interrater reliability values were assessed by Cronbach alpha inter-item correlation. As a rule, intraclass correlations greater than or equal to 0.80 are considered adequate.

CHAPTER 5

RESULTS

Interrater reliability of the Modified Mallampati Tongue score, craniofacial posture cephalometric measurements, and craniofacial morphology measurements were excellent (correlation coefficients: 0.84-0.99) except for Tongue Height (correlation coefficient: 0.73). Intrarater reliability values of the Modified Mallampati Tongue score, craniofacial posture cephalometric measurements, and craniofacial morphology measurements were also excellent (correlation coefficients: 0.84-0.99).

5.1 Modified Mallampati Tongue Scores and Patient Demographics

A total of 200 patients were included, consisting of 145 (72.5%) women and 55 (27.5%) men. The age range was 7-73 years, and the mean age was 19.56 years (SD 10.75). Demographically, the study population was 54% African American, 35.6% Hispanic, 8.5% Caucasian, and 1.5% Asian. MMT III was the most prevalent score (34%) found in the sample (Table 1).

Table 1: *Baseline Patient Characteristics*

N	200
Age, mean (SD)	19.56 (10.75)
Gender (%)	
Male	55 (27.5%)
Female	145 (72.5%)
Race/Ethnicity (%)	
African American	107 (53.5%)
Hispanic	73 (36.5%)
Caucasian	17 (8.5%)
Asian	3 (1.5%)
Prevalance of MMT (%)	
I	32 (16 %)
II	59 (29.5%)
III	68 (34%)
IV	41 (20.5%)

No associations between MMT and age, gender, race/ethnicity were observed with Chi-square tests (Table 2).

Table 2: *Chi-Square Test Results | MMT x Patient Demographics*

MMT x Race/Ethnicity			
	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	9.364[a]	9	0.404
Likelihood Ratio	9.155	9	0.423
Linear-by-Linear Association	0.914	1	0.339
N of Valid Cases	197		

a. 7 cells (43.8%) have expected count less than 5. The minimum expected count is .49.

MMT x Gender			
	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	13.963[a]	3	0.003
Likelihood Ratio	14.028	3	0.003
Linear-by-Linear Association	5.435	1	0.020
N of Valid Cases	200		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 8.80.

MMT x Age			
	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	8.971[a]	6	0.175
Likelihood Ratio	8.819	6	0.184
Linear-by-Linear Association	0.938	1	0.333
N of Valid Cases	200		

a. 4 cells (33.3%) have expected count less than 5. The minimum expected count is 2.08.

5.2 Modified Mallampati Tongue Scores and Craniofacial Head Posture

A one-way ANOVA found significant differences in cephalometric measurements of hyoid plane angle and vertical position of hyoid bone to the mandible and neck with different MMT (Table 3). Further post hoc t-tests showed significant differences in cephalometric measurements of hyoid plane angle between MMT I & MMT III (*p*=0.018) and MMT III & MMT IV (*p*=0.012); vertical position of hyoid bone to mandible between MMT I & MMT III (*p*=0.002) and MMT II & MMT III (*p*=0.008); and vertical position of hyoid bone to neck between MMT I & MMT III (*p*=0.002) and MMT I & MMT IV (*p*=0.014).

Table 3: *Significant One-Way ANOVA Results | MMT x Craniofacial Head Posture*

		Sum of Squares	df	Mean Square	F	Sig.
Hyoid Plane Angle	Between Groups	712.030	3	237.343	3.049	0.030
	Within Groups	15255.269	196	77.833		
Vertical Position of Hyoid to Mandible	Between Groups	416.782	3	138.927	4.293	0.006
	Within Groups	6342.574	196	32.360		
Vertical Position of Hyoid to Neck	Between Groups	375.215	3	125.072	3.505	0.016
	Within Groups	6994.875	196	35.688		

There was a statistically significant positive correlation between the increase in MMT and increase in vertical position of the hyoid bone to mandible (Figure 4) and neck (Figure 5) cephalometric measurements in Pearson's correlation test (Table 4).

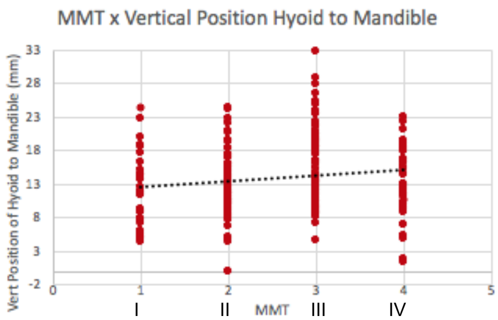

Figure 4: Positive Correlation Between MMT and Vertical Position of Hyoid Bone to Mandible (*p*=0.048)

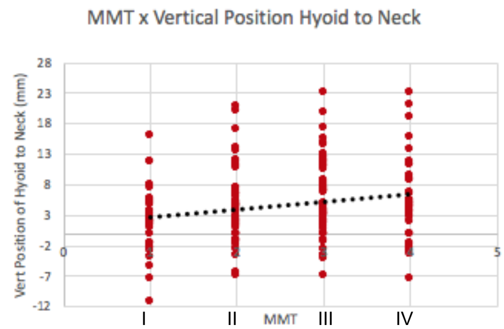

Figure 5: Positive Correlation Between MMT and Vertical Position of Hyoid Bone to Neck (*p*=0.004)

There were positive correlations found between MMT and OPT-HOR, CVT-HOR, OPT-SN, SN-VERT, hyoid plane angle and negative correlations found between MMT and Tongue Length, Tongue Height, and CVT-SN, however these results were statistically insignificant (p=0.181-0.950), as seen in Table 4.

Table 4: *Correlation between MMT x Craniofacial Head Posture*

		Tongue Length	Tongue Height	Vert Position of Hyoid to Mand	Vert Position of Hyoid to Neck	Hyoid Plane Angle
MMT (I-IV) N=200	Pearson Correlation	-0.004	-0.094	.140*	0.047	0.025
	Sig. (2-tailed)	0.950	0.187	0.048	0.512	0.723

		OPT_ HOR	CVT_ HOR	OPT_ SN	CVT_ SN	SN_ VERT
MMT (I-IV) N=200	Pearson Correlation	0.025	0.037	0.020	-0.024	0.095
	Sig. (2-tailed)	0.723	0.599	0.782	0.738	0.181

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

5.3 Modified Mallampati Tongue Scores and Craniofacial Morphology

A one-way ANOVA found significant differences in cephalometric measurements of ANB and SNB with different MMT (Table 5). Further post hoc t-tests showed significant differences in cephalometric measurements of ANB between MMT I & MMT III (p=0.036), MMT I & MMT IV (p=0.004), and MMT II & MMT IV (p=0.012); and SNB between MMT I & MMT III (p=0.022) and MMT I & MMT IV (p=0.021).

Table 5: *Significant One-Way ANOVA Results | MMT x Craniofacial Morphology*

		Sum of Squares	df	Mean Square	F	Sig.
ANB	Between Groups	105.326	3	35.109	3.950	0.009
	Within Groups	1742.155	196	8.889		
SNB	Between Groups	198.288	3	66.096	3.246	0.023
	Within Groups	3990.534	196	20.360		

There was a statistically significant positive correlation between the increase in MMT and increase in ANB and Wits (Figure 6 & 7); and an significant inverse correlation between the increase in MMT and decrease in SNB and Pog-Na:Perp (Figure 8 & 9) (Table 6). There were positive correlations found between MMT and A-Na:Perp and negative correlations found between MMT and SNA and Vertical Ratio, however these results were statistically insignificant (p=0.415-0.530), as seen in Table 6.

Table 6: *Correlation between MMT x Craniofacial Morphology*

		ANB	SNA	SNB	Wits	A-Na:Perp	Pog - Na:Perp	Vertical Ratio
MMT (I-IV) N=200	Pearson Correlation	.238**	-0.058	-.209**	.170*	0.045	-.142*	-0.046
	Sig. (2-tailed)	0.001	0.415	0.003	0.016	0.530	0.045	0.521

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

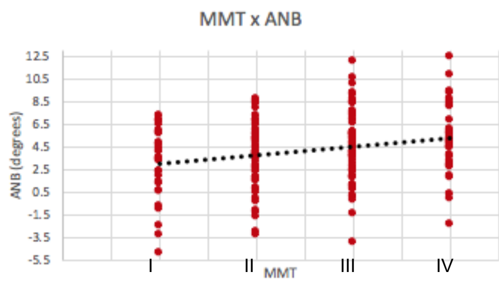

Figure 6: Positive Correlation Between MMT and ANB (*p*=0.002)

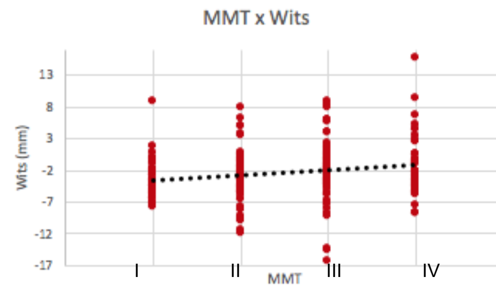

Figure 7: Positive Correlation Between MMT and Wits (*p*=0.016)

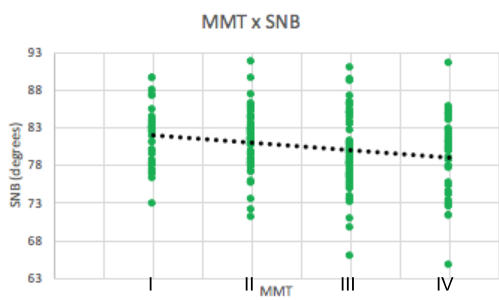

Figure 8: Negative Correlation Between MMT and SNB (p=0.003)

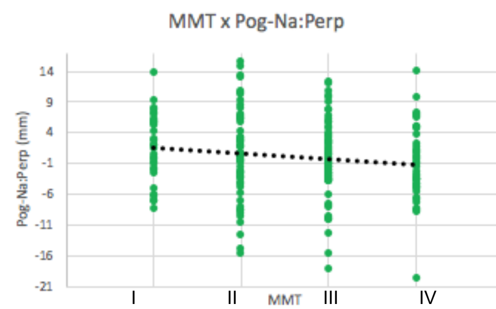

Figure 9: Negative Correlation Between MMT and Pog-Na:Perp (*p*=0.045)

5.4 Craniofacial Head Posture and Craniofacial Morphology

The associations between different postural relations and craniofacial morphology were studied by correlation analysis. The correlation results are presented in Table 7.

A clear pattern of significant associations was observed. Two variables expressing increase in craniocervical angulation (OPT-SN, CVT-SN) showed correlation with variables expressing retrognathic maxilla (SNA) and mandible (SNB, Pog-Na:Perp), hyperdivergent (decreased vertical ratio), and Class II skeletal morphology (ANB). One variable expressing an extended craniofacial head posture (SN-VERT) showed correlation with retrognathic maxilla (SNA) and mandible (SNB) and a hyperdivergent morphology (decreased vertical ratio). Increased hyoid plane angle correlated with retrognathic mandible (SNB) and Class II skeletal morphology (ANB). An increased tongue length and height correlated with a prognathic maxilla (SNA, A-Na:Perp) and mandible (SNB, Pog-Na:Perp) morphology with an increase in tongue height also correlated with a hypodivergent morphology (increased vertical ratio).

Table 7: *Correlations between Craniofacial Head Posture x Morphology*

		ANB	SNA	SNB	Wits	A-Na:Perp	Pog-Na:Perp	Vertical Ratio
Tongue Length	Pearson Correlation	0.128	.184**	0.097	-0.045	.254**	0.041	0.035
	Sig. (2-tailed)	0.071	0.009	0.172	0.523	0.000	0.563	0.626
Tongue Height	Pearson Correlation	-0.135	0.076	.166*	-0.098	0.046	.152*	.270**
	Sig. (2-tailed)	0.057	0.283	0.019	0.166	0.516	0.031	0.000

		ANB	SNA	SNB	Wits	A-Na:Perp	Pog-Na:Perp	Vertical Ratio
Hyoid_Mand	Pearson Correlation	0.067	-0.042	-0.080	0.006	-0.028	-0.030	-0.009
	Sig. (2-tailed)	0.344	0.557	0.262	0.927	0.697	0.670	0.901
Hyoid_Neck	Pearson Correlation	0.127	0.097	0.019	0.015	0.031	-0.052	0.137
	Sig. (2-tailed)	0.072	0.173	0.793	0.829	0.661	0.462	0.053
OPT_HOR	Pearson Correlation	-0.090	0.060	0.116	0.087	0.009	0.138	0.128
	Sig. (2-tailed)	0.207	0.401	0.101	0.223	0.901	0.052	0.072
CVT_HOR	Pearson Correlation	-0.080	0.039	0.090	0.027	0.008	0.115	0.117
	Sig. (2-tailed)	0.261	0.581	0.207	0.709	0.912	0.106	0.099
OPT_SN	Pearson Correlation	.181*	-.339**	-.448**	0.087	0.035	-.177*	-.281**
	Sig. (2-tailed)	0.010	0.000	0.000	0.220	0.621	0.012	0.000
CVT_SN	Pearson Correlation	0.136	-.366**	-.445**	0.071	0.041	-0.127	-.290**
	Sig. (2-tailed)	0.055	0.000	0.000	0.320	0.568	0.074	0.000
SN_VERT	Pearson Correlation	0.042	-.549**	-.562**	0.118	0.084	0.040	-.274**
	Sig. (2-tailed)	0.559	0.000	0.000	0.098	0.239	0.575	0.000
Hyoid_Angle	Pearson Correlation	.143*	-0.051	-.145*	0.085	-0.002	-0.101	-0.022
	Sig. (2-tailed)	0.043	0.476	0.040	0.233	0.979	0.154	0.757

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

CHAPTER 6

DISCUSSION

The tongue is an important part of the postural apparatus of the head and jaws as its shape and position impact the airway patency in the hypopharynx (Yucel et al., 2005). This contributes to changes in head posture as postural adaptations occur at the level of the oropharynx to maintain airway flow with a lower tongue posture and hyoid bone in relation to the mandible (Ballard, 1951; and Tourné, 1991). The head is generally extended to compensate for smaller airway space (Ucar et al., 2012). As a result, this accommodative prolonged lower mandibular posture and extended head posture influences the load on areas of the craniovertebral region (Darnell, 1983). During growth, the dentoalveolar complex and mandible adapt to this changed position resulting in variations in craniofacial morphology and growth (Harvold, 1973).

The dynamic nature of the tongue makes it challenging to assess tongue size and posture and its effects on craniofacial growth. Numerous studies have attempted to develop various techniques to evaluate tongue size in vivo (Tamari, 1991; and Oliver 1986) and have used an assortment of imaging techniques to assess tongue volume and posture (Cuccia, 2007; Roehm, 1982; Uysal, 2013; and Iida-Kondo, 2006). However, with the hyoid bone and head posture affecting tongue posture and relative tongue volume, none of these studies have considered these factors nor produced a simple and reproducible method to assess tongue posture. The systematic approach of the anesthesiologic airway assessment, the Modified Mallampati Tongue Score (MMT), classifying tongue position into four categories (Samsoon and Young, 1987) leads us to evaluate the application of this scoring system in the context of craniofacial growth. The purpose of this study was to investigate if a relationship exists between the Modified Mallampati Tongue Score and variations in craniofacial posture and morphology as depicted in a lateral cephalogram.

All subjects selected for this study have had no prior orthodontic treatment to evaluate the tongue's position without any treatment effects and to have effects of growth and head posture completely attribute the tongue position.

6.1 Correlation of Modified Mallampati Tongue Scores and Craniofacial Head Posture

Our first objective was to correlate MMT to variations in the postural position of the tongue, hyoid bone, cervical spine, and cranium. We found a higher MMT correlated to lower position of the hyoid bone in relation to both the mandible and cervical spine. This may be due to the higher tongue posture, such as in MMT III and IV, causing a decreased distance between the tongue base and the roof of the mouth, resulting in a smaller oral airway. Several studies (Liistro, 2003; Rodrigues, 2010; Kim, 2013) have reported a combination of a high Mallampati score and nasal obstruction as risk factors for sleep-disordered breathing, including obstructive sleep apnea (OSA). With higher MMT, the base of the tongue is disproportionately large, or the oropharyngeal cavity is disproportionately small, the tongue masks the visibility of the faucial pillars and uvula (Mallampati, 1985), which increases the risk of obstructive sleep apnea (Nuckton, 2006).

In this study, the lower hyoid position with head extension increases the sagittal extension of the pharyngeal airway to establish normal breathing function as an adaptive mechanism.

Similarly, Adamidis (1983) and Subtelny (1980) also found a lowered posturing of the hyoid bone, which forces the tongue anteriorly and causes compensatory change in the child's mode of breathing. Furthermore, the hyoid plane angle was significantly higher in MMT IV than other MMT, supporting a more extended head posture caused by a higher MMT and tongue posture and association with a low position of the hyoid bone. These results are similar to studies that found characteristics in subjects with OSA (Wong, 2005; Pracharktam, 1996; Solow, 1993) who were reported to have an extended natural head posture, reduced posterior airway space, an abnormally long soft palate, and a low position of the hyoid bone. Additionally, the more severe the OSA, the more extended the natural head position indicated by an increase in craniocervical angles (Sokucu, 2016).

6.2 Correlation of Modified Mallampati Tongue Scores and Craniofacial Morphology

Another objective of this study was to correlate MMT to variations in size, shape, and position of the craniofacial components such as the maxilla and mandible. In this study, higher MMT were found to be associated with Class II skeletal morphology with retrognathic mandibular growth. Mandibular retrognathism was also found to be more associated with MMT III and IV than MMT I, while Class II skeletal morphology is seen more in MMT IV than MMT I. This may be attributed to the higher tongue position resulting in head extension, which affects craniofacial development of the maxilla and mandible into a Class II skeletal pattern. Solow and Tallgren (1976) had similar results by finding a connection between extended head posture and facial retrognathism. Farheen (2019) found the resting tongue posture of skeletal Class II patients to be higher as compared to Class I and Class III. However, they found that lowered tongue posture was most posterior and prevalent in skeletal Class III subjects (Farheen, 2019; Primozic, 2013). It has been recognized that the development of the craniomaxillary complex is influenced by both proprioceptive extraoral and intraoral forces such as the tongue (Ucar et al., 2012). Graber (1958) also believed muscle posture to be more important than muscle function in molding the hard tissues. In a study by Lowe (1985), an association was found between a forward tongue posture and an anterior open bite, a large overjet, a steep mandibular plane, and large gonial angle. Subrahmanya (2014) also reported a relationship between posture of tongue and skeletal facial pattern in vertical plane with the dorsum of the tongue seen to be placed higher in subjects with a vertical growth pattern. However, our study did not find any significant correlations with MMT and vertical facial patterns or cephalometric dimensions. This may be attributed to the small sample size as well as the inclusion of a single cephalometric measurement to assess the vertical skeletal relationships in this study in contrast to the two analyses included to assess the sagittal skeletal relationship. By increasing the sample size and including additional vertical measurements – such as FMA, SN-MP, Y-axis, or Facial Axis – in this study, a significant correlation can be determined between MMT and vertical facial patterns.

6.3 Correlation of Modified Mallampati Tongue Scores and Patient Demographics

Numerous studies (Liistro, 2003; Rodrigues, 2010; Kim, 2013, Nuckton, 2006) have established the relationship between obstructive sleep apnea and MMT. This has led to an influx of research done on anthropometric and demographic variables associated with OSA and its relationship with MMT. In this study no association was found between the different MMT and race and ethnicity. These results, however, are different from Albustami (2011) who found higher MMT (III/IV) in African Americans than Caucasians with OSA. Consequently, Lam (2005) found Asians to have a higher MMT, larger thyromental angles, and shorter thyromental distances than white subjects.

Regarding age, Ouchi (2020) and Moon (2013) found MMT III and IV in older age groups, while this study found no significant correlations between MMT and various age groups. When associating gender with MMT, our results showed no difference in prevalence of MMT between male and female subjects in contrast to a study by Menon (2017), who found a higher proportion of MMT III and IV in males than females. However, Uribe (2015) found MMT to be an equally strong predictor of difficult intubation in adult patients of both genders.

In our study, tongue size (height and length) did not vary between various age groups. This may be due to growth the development of the tongue reaching its approximate adult size by 8 years of age (Profitt, 1975) which is concurrent with the lower limit of the age range of this study’s sample population.

There were no significant differences in tongue height and length with regards to gender, race, or ethnicity. This is in contrast to other studies (Dareze, 2017; Shastri, 2015) that found tongue length and height to be significantly larger in males than females. There is insufficient research associating cephalometric measurements of tongue height and length to race and ethnicity.

6.4 Correlation of Craniofacial Head Posture and Craniofacial Morphology

A dynamic relationship exists between craniofacial head posture and craniofacial development. Solow (1992) inferred that head posture influenced the direction of growth of the face. A comprehensive set of associations were found in this study between variables depicting extended craniofacial head posture and specific craniofacial morphological characteristics. This study found that the extension of the head in relation to the cervical column were found in subjects with a more retrognathic maxilla and mandible, hyperdivergent, and Class II skeletal morphology. Extended head posture in relation to true vertical was also correlated with facial retrognathism and a hyperdivergent morphology. A cross-section study by Solow and Tallgren (1976) found similar results by finding an association between craniocervical extension and large anterior and small posterior facial heights, small antero-posterior cranio-facial dimensions, large inclination of the mandible to the anterior cranial base and the nasal plane, a large cranial base angle, and a small bony nasopharyngeal space. This may be alluded to the soft-tissue stretching hypothesis by Solow and Kreiborg (1977) which described obstruction of the upper airways to cause an increase in craniocervical angulation to facilitate respiration. The stretching of the soft tissue with head extension redirects the forward growth of the jaws in a more downward direction, resulting in a more retrognathic and hyperdivergent morphology.

An increased hyoid plane angle was correlated with a retrognathic mandible and Class II skeletal morphology in this study. The hyoid bone facilitates maintaining the airway and upright posture position of the head (Bibby, 1979). The increased hyoid plane angle demonstrates head extension in relation to the hyoid bone, which may be directly affected by airway obstruction or inability for the hyoid to maintain a more favorable head posture, leading to the retrognathic craniofacial development of the mandible exacerbating the Class II morphology.

Peat (1968) considered tongue size to have been one of the main molding forces within the oral environment during craniofacial development. In this study, a prognathic maxilla and mandible were found to be associated with larger tongues. An increased tongue height also correlated with a hypodivergent morphology. Cohen and Vig (1976) noticed that the increase in tongue size was harmonious with the descent of the tongue which together maintained function and influenced growth.

6.5 Limitations

A limitation of this study was the cohort size and selection of the subjects being specific to an orthodontic population in North Philadelphia with patient demographics indicative of this region and treatment type. A larger and more diverse sample size may find association of MMT with patient demographics.

Interrater variability in head positioning with the cephalostat and when capturing the intraoral photograph of the MMT may affect data collection concerning measurements involving head posture in relation to the true vertical and horizontal and MMT scoring.

6.6 Future Directions

Further research and increase in cohort size can determine specific predictive ranges of craniofacial posture and morphology measurements with various MMT scores. If significant results are found, MMT scores could be used a predictors of craniofacial growth patterns and can be used in routine diagnosis and treatment planning.

A follow up to this study can be to correlate MMT to dental arch width and arch form prior to orthodontic treatment and vice versa - changes that may occur to MMT after changes in dental arch width and form are made with orthodontic treatment. This can be taken a step further by evaluating treatment effects on tongue position by assessing MMT pre and post orthodontic treatment and what changes occur by various treatment plans and treatment mechanics.

Another direction to this study would be to evaluate MMT scores immediate and long-term post orthodontic treatment to determine MMT changes and correlate MMT to degrees of relapse. This could be used as predictive measures for relapse potential and to establish appropriate treatment that can produce long term stability and outcomes.

CHAPTER 7

CONCLUSION

The conclusions of this study are as follows:

- A higher MMT correlates to a Class II skeletal morphology and extended craniofacial posture.
- Preliminary results suggest high tongue position influences Class II craniofacial morphology, enhancing maxillary prognathic growth and mandibular deficiency.
- This suggests that MMT can be a potential predictor of craniofacial growth patterns, enhancing the prognosis and long-term stability of orthodontic treatment.

BIBLIOGRAPHY

Adamidis IP, Spyropoulos MN. The effects of lymphadenoid hypertrophy on the position of the tongue, the mandible and the hyoid bone. Eur J Orthod 1983;5:287–94.

Albustami O, Rahman K, Sharma S. Racial differences in the predictive value of Mallampati score for obstructive sleep apnea. Chest 2011; 140(4): 815A

Amadsun FE, Adudu OP, Sadiq A. Effects of position and phonation on oropharyngeal view and correlation with laryngoscopic view. Nig J of Clin Prac 2010; 13(4): 417-420.

Arya D, Tripathi A, Singh SV, Tripathi S, Nagar A, Mishra A. A pilot study to evaluate posttreatment cephalometric changes in subjects with OSA. J Prosthet Dent 2010;103(3):170–177

Baker RE. The tongue and dental function. Am J Orthod. 1954;40:927-9.

Ballard C.F. The facial musculature and anomalies of the dentoalveolar structure. Trans. Eur. Orthod. Soc. 1951:137–148.

Bandy HE, Hunter WS. Tongue volume and the mandibular dentition. Am J Orthod 1969;56(2):134–42.

Bell WA. Muscles pattern of late fetal tongue tip. Angle Orthod 1970;40:262-5.

Bibby RE. The position of the hyoid bone in orthodontic patients, Master's thesis, 1979 University of the Witwatersrand.

Bibby RE, Preston CB. The hyoid triangle. Am J Orthod Dentofac Orthop 1981;80:92-97.

Bjork A, Skieller, V. Facial development and tooth eruption. Am.J. Orthod, 1972: 62: 339-383.

Bosma, JF. Oral and pharyngeal development and function, J. D. Res. 1963; 42: 375-380.

Brodie AG. Late growth changes in the human face. Angle Orthodont 1953; 23:146-157.

Chaves et al. Craniocervical posture and hyoid bone position in children with mild and moderate asthma and mouth breathing. International Journal of Pediatric Otorhinolaryngology 2010; 74:1021–1027.

Cohen AM, Vig PS. A serial growth study of the tongue and intermaxillary space. Angle Orthod 1976;46(4):332–7.

Cuccia AM, Campisi G, Cannavale R, Colella G. Obesity and craniofacial variables in subjects with obstructive sleep apnea syndrome: comparisons of cephalometric values. Head Face Med. 2007;3:41.

Dareze, A., Delatte, M., Liistro, G., Majzou, Z. Cephalometrics of pharyngeal airway space in Lebanese Adults. International Journal of Dentistry Vol 2017, Article 3959456, 11 pages.

Darnell, M.W., A proposed chronology of events for forward head posture. Cranio l 1983. (4), 49–54.

Di Francesco, Renata et al. Craniofacial morphology and sleep apnea in children with obstructed upper airways: differences between genders. Sleep medicine 2012;13(6):616-20.

Doual-Bisser A, Doual JM, Crocquet M. Hyoglossal balance and vertical morphogenesis of the face. Orthod Fr 1989;60(2):527–32.

Enlow DH. Handbook of facial growth. 2nd edition. Philadelphia: WB Saunders Co.; 1982.

Farheen F, Mubassar, F. The assessment of resting tongue posture in different sagittal skeletal patterns. Dental Press J Orthod. 2019; 24(3):55-63

Frankel F, Frankel C. Orofacial orthopedics with the functional regulator. Basel: Karger; 1989.

Frohlich K, Thuer U, Ingervall B. Pressure from the tongue on the teeth in young adults. Angle Orthod 1991;61(1):17–24.

Frohlich K, Ingervall B, Schmoker R. Influence of surgical tongue reduction on pressure from the tongue on the teeth. Angle Orthod 1993;63(3):191–8.

Graber, T. M.: Implementation of the Roentgenographic Cephalometric Technique, AM. .J. Orthodontic. 1958; 44: 906.

Greenfeld M, Tauman R, DeRowe A, et al. Obstructive sleep apnea syndrome due to adenotonsillar hypertrophy in infants. Int J Pediatr Otorhinolaryngol 2003;67:1055–60.

Guilleminault C, Riley R, Powell N: Obstructive sleep apnea and abnormal cephalometric measurements. Implications for treatment. Chest 1984; 86: 793-794.

Gungor AY, Turkkahraman H, Yilmaz HH, Yariktas M. Cephalometric comparison of obstructive sleep apnea patients and healthy controls. Eur J Dent. 2013;7(1):48–54.

Harvold EP, Vargervik K, Chierici G. Primate experiments on oral sensation and dental malocclusions. Am J Orthod 1973;63(5):494–508.

Iida-Kondo C, Yoshino N, Kurabayashi T, Mataki S, Hasegawa M, Kurosaki N. Comparison of tongue volume/oral cavity volume ratio between obstructive sleep apnea syndrome patients and normal adults using magnetic resonance imaging. J Med Dent Sci. 2006;53(2):119–126.

Ingervall B, Schmoker R. Effect of surgical reduction of the tongue on oral stereognosis, oral motor ability, and the rest position of the tongue and mandible. Am J Orthod Dentofacial Orthop 1990;97(1):58–65.

Jacobsen, A. The “Wits” appraisal of jaw disharmony. Am J Orthod 1975; 67(2): 125-138

Kim HY, Jeong JI, Dhong HJ, et al. Nasal obstruction and palate-tongue position on sleep-disordered breathing. Clin Exp Otorhinolaryng 2013; 6(4):226-230

Kobayashi I, Perry A, Rhymer J, et al. Inspiratory coactivation of the genioglossus enlarges retroglossal space in laryngectomized humans. J Appl Physiol. 1996;80(5):1595-1604.

Lam, B et al. Craniofacial profile in Asian and white subjects with obstructive sleep apnoea. Thorax 2005;60(6):504-10.

Lauder R, Muhl ZF. Estimation of tongue volume from magnetic resonance imaging. Angle Orthod 1991;61(3):175–84.

Lee A, Fan L, Gin T, Karmakar MK, Kee W. A systematic review (meta-analysis) of the accuracy of the Mallampati tests to predict difficult airway. Anesth Analg 2006; 102: 1867-78.

Lewis M, Karamati S, Benumof JL, Berry CC. What is the best way to determine oropharyngeal classification and mandibular space length to predict difficult laryngoscopy? Anaesthesiology 1994; 81: 69-75.

Liistro G, Rombaux P, Belge C, Dury M, Aubert G, Rodenstein DO. High Mallampati score and nasal obstruction are associated risk factors for obstructive sleep apnea. Eur Respir J 2003; 21: 248–252.

Linder-Aronson S: Adenoids: their effect on mode of breathing and nasal airflow and their relationship to characteristics of the facial skeleton and the dentition. Acta Otolaryngol 1970; [Suppl 2651 (Stockh).

Lowe AA, Takada K, Yamagata Y, Sakuda M. Dentoskeletal and tongue soft-tissue correlates: a cephalometric analysis of rest position. Am J Orthod 1985;88(4):333–41.

Lowe AA, Santamaria JD, Fleethan JA, Price C. Facial morphology and obstructive sleep apnea. Am J Orthod Dentofac Orthop 1986;90:484-491.

Mallampati SR. Clinical signs to predict difficult tracheal intubation (hypothesis). Can Anaseth Soc J. 1983; 30:316-17

Mallampati SR, Gatt SP, Gugino LD, Desai SP, Waraksa B, Freiberger D, Liu PL. A clinical sign to predict difficult tracheal intubation: a prospective study. Can Anaesth Soc J. 1985;32:429–434.

Manabe Y, Iwamoto S, Miyawaki H, Seo K, Sugiyama K. Mallampati classification without tongue protrusion can predict difficult tracheal intubation more accurately than the traditional Mallampati classification. Oral Sci Internat 2014; 11:52-55

McNamara JA. Influence of respiratory pattern on craniofacial growth. Angle Orthod 1981;51:269–300.

McNamara JA Jr. A method of cephalometric evaluation. Am J Orthod 1984; 86: 449-469.

Menon SM, Sampangiramaiah S, Mathew M. Cross sectional observational study performed to see for relation of Mallampati score and extended Mallampati score with body mass index. J Clin Diag Res 2017; 11(5) UG01-UG03.

Mezon BJ, West P, MaClean JP, Kryger MH: Sleep apnea in acromegaly. Am J Med 1980; 69: 615-618.

Miyamoto K, Ozbek MM, Lowe AA, Fleetham JA. Effect of body position on tongue posture in awake patients with obstructive sleep apnoea. Thorax 1997;52(3):255–259.

Moon HY, Baek CW, Kim JS, Koo GH, Kim JY, Woo YC, et al. The causes of difficult tracheal intubation and preoperative assessments in different age groups. Korean J Anesthesiol. 2013;64(4):308–14.

Moorrees CF, Kean MR. Natural head position, a basic consideration in the interpretation of cephalometric radiographs. Am J Phys Anthropol 1958;16:213-234.

Moss, M. Salentijn L.The primary role of functional matrices in facial growth. Am J Orthod 1969; 55 (6):566-577.

Moss ML. Neurotrophic processes in orofacial growth. J Dent Res 1971;50(6):1492–4.

Nuckton TJ, Glidden DV, Browner WS, et al. Physical examination: Mallampati Score as an independent predictor of obstructive sleep apnea. Sleep 2006: 29; 903-8.

Oates JD, Oates PD, Pearsall FJ, McLeod AD, Howie JC. Phonation affects Mallampati class. Anesthesia. 1990;45:984.

Oliver RG, Evans SP. Tongue size, oral cavity size and speech. Angle Orthod 1986;56(3):234–43.

Orr WC, Martin RJ: Obstructive sleep apnea associated with tonsillar hypertrophy in adults. Arch Intern Med 1981; 141: 990-992.

Ouchi, K., Hosokawa, R., Yamanaka, H, Nakajima Y, Nakamura Y, Kishimoto J. Mallampati test with phonation, tongue protrusion and supine position is most correlated with Cormack–Lehane test. Odontology 2020. https://doi.org/10.1007/s10266-020-00490-3

Peat JH. A cephalometric study of tongue position. Am J Orthod. 1968;54:339–51.

Petrovic AG. Mechanisms and regulation of mandibular condylar growth.. Acta Morphol Neerl Scand 1972;10:25-34.

Piccin, Chaiane Facco et al. Craniocervical Posture in Patients with Obstructive Sleep Apnea. International archives of otorhinolaryngology 2016; *20*(3):189-95.

Pracharktam N, Nelson S, Mark GH, Broadbent BH, Redline S, Rosenberg C, et al. Cephalometric assessment in obstructive sleep apnea. Am J Orthod Dentofacial Orthop 1996;109:410-9.

Primozic J, Farčnik F, Perinetti G, Richmond S, Ovsenik M, The association of tongue posture with the dentoalveolar maxillary and mandibular morphology in Class III malocclusion: a controlled study, European Journal of Orthodontics, 2013;35(3):388–393.

Proffit WR, Mason RM. Myofunctional therapy for tongue-thrusting: background and recommendations. *J Am Dent Assoc.* 1975;90:403–411.

Proffit WR. Equilibrium theory revisited: factors influencing position of the teeth. Angle Orthod. 1978 July;48(3):175-86.

Roehm EG. Computed tomographic measurement of tongue volume relative to its surrounding space. Am J Orthod. 1982;81(2):172.

Rodrigues M, Dibbern RS, Goulart CK. Nasal obstruction and high Mallampati score as risk factors for obstructive sleep apnea. Braz J Otorhinolaryngol 2010; 76(5):569-9.

Samsoon GL, Young JR. Difficult tracheal intubation: a retrospective study. Anaesthesia. 1987;42:487–490.

Santos, A, Mathias, L, Gozzani, Ji, Watanabe, M. Difficult intubation in children: applicability of the Mallampati index. Revista Brasileira de Anestesiologia, 2011;61(2): 159-162.

Shastri D, Tandon P, Nagar A, Singh A. Cephalometric norms for the upper airway in a healthy North Indian population. Contemp Clin Dent. 2015 Apr-Jun;6(2):183-8.

Sicher, H.: Oral Anatomy, St. Louis, 1960, The ‘C. V. Mosby Company, chap. 4, p. 195.

Silva, VG et al. Correlation between cephalometric data and severity of sleep apnea. Brazilian journal of otorhinolaryngology 2014; 80 (3): 191-5.

Siriwat P, Jarabak J. Malocclusion and facial morphology is there a relationship? An Epidemiologic Study. Angle Orthod 1985;55 (2):127-38.

Skolimowski J, Urbanski M, Stopa J, Naroznik K. Microgenia as a factor making endotracheal intubation impossible. Anaesthesia, Resuscitation and Intensive Therapy. 1975; 3:273-6

Solow B, Tallgren A. Natural head position in standing subjects. Acta Odontol Scand 1976;29:591-607.

Solow B, Tallgren, A. Head posture and craniofacial morphology. Am. J. Phys. Anthropol. 1976: 44: 417-436.

Solow B, Kreiborg S. Soft-tissue stretching: a possible control factor in craniofacial morphogenesis. Scand J Dent Res 1977;85:505-7.

Solow B, Siersbaek-Nielsen S, Greve E: Airway adequacy, head posture, and craniofacial morphology. Am J Orthod 1984; 86: 214-223.

Solow B, Siersbaek-Nielsen S. Cervical and craniocervical posture as predictors of craniofacial growth. Am J Orthod Dentofac Orthop 1992;101:449-58.

Solow B, Ovesen J, Nielsen PW, Wildschiodtz G, Tallgren A. Head posture in obstructive sleep apnoea. Eur J Orthod 1993;15:107-14.

Steiner CC. Cephalometrics for you and me. Am J Orthod 1953; 39: 729-755.

Subrahmanya, R, Gupta, S. Assessment of comparison of tongue posture in individuals with different vertical facial patterns. Journal of Orofacial Research 2014;4(2):67-71.

Subtelny JD. Oral respiration: facial maldevelopment and corrective dentofacial orthopedics. Angle Orthod 1980;50:147–64.

Tamari K, Shimizu K, Ichinose M, Nakata S, Takahama Y. Relationship between tongue volume and lower dental arch sizes. Am J Orthod Dentofacial Orthop 1991;100(5): 453–8.

Tham EJ, Gildersieve CD, Sanders LD, Mapleson WW, Vaughn RS. Effects of posture, phonation, and observer on Mallampati classification. Br J Anaesth 1992; 68: 32-8.

Tourné L.P. Growth of the pharynx and its physiologic implications. Am. J. Orthod. Dentofacial Orthop. 1991;99(2):129–139.

Turner S, Nattrass C, Sandy JR. The role of soft tissues in the aetiology of malocclusion. Dent Update 1997;24(5): 209–14.

Ucar FI, Ekizer A, Uysal. Comparison of craniofacial morphology, head posture and hyoid bone position with different breathing patterns. Saudi Dent J. 2012 Jul; 24(3-4): 135–141.

Uribe A, Zvara D, Puente E, Otey A, Zhang J, Bergese S. BMI as a predictor for potential difficult tracheal intubation in males. Front Med (Lausanne) 2015; 2:38

Uysal T, Yagci A, Ucar FI, Veli I, Ozer T. Cone-beam computed tomography evaluation of relationship between tongue volume and lower incisor irregularity. Eur J Orthod. 2013;35(5):555–562.

Vig PS, Cohen AM. The size of the human tongue shadow in different mandibular postures. Br J Orthod 1974;1(2):41–3. 16.

Vig PS, Cohen AM. The size of the tongue and the intermaxillary space. Angle Orthod 1974;44(1):25–8.

Wilson ME, John R. Problems with the Mallampati sign. Anaesthesia. 1990;45:486–7.

Wong ML, Sandham A, Ang PK, Wong DC, Tan WC, Huggare J. Craniofacial morphology, head posture, and nasal respiratory resistance in obstructive sleep apnoea: an inter-ethnic comparison. Eur J Orthod 2005;27:91-7.

Yoo E, Murakami S, Takada K, Fuchihata H, Sakuda M. Tongue volume in human female adults with mandibular prognathism. J Dent Res 1996;75(12):1957–62.

Yucel A, Unlu M,Haktanir A, AcarM, Fidan F. Evaluation of the upper airway cross-sectional area changes in different degrees of severity of obstructive sleep apnea syndrome: cephalometric and dynamic CT study. AJNR Am J Neuroradiol 2005;26(10):2624–2629.

Zorick F, Roth T, Kramer M, Fless H: Exacerbation of upper-airway sleep apnea by lymphatic lymphoma. Chest 1980; 77: 689-690.

APPENDICES

APPENDIX A: INSTITUTION REVIEW BOARD HIPAA WAIVER & APPROVAL (Protocol Number: 27839)

Temple University
Office of the Vice President for Research

Research Integrity & Compliance
Student Faculty Center
3340 N. Broad Street, Suite 304
Philadelphia PA 19140

Institutional Review Board
Phone: (215) 707-3390
Fax: (215) 707-9100
e-mail: irb@temple.edu

Full Accreditation

Approval of the waiver of HIPAA authorization

Date: 11-Feb-2021

Protocol Number: 27839
PI: SCIOTE, JAMES J.
Committee: A1
Project Title: Correlation between Modified Mallampati Tongue Score with Variations in Craniofacial Posture & Morphology in a Lateral Cephalogram

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On 11-Feb-2021, the Temple IRB approved the waiver or alteration of HIPAA authorization for the protocol approved with submission # **27839-0002**. The waiver or alteration was reviewed and approved under expedited review procedures.

If this is an alteration of HIPAA authorization, additional information regarding the alteration will be provided below or in a separate manual letter.

The IRB has determined that all the specified criteria for a waiver of HIPAA authorization were met:

The description of the Protected Health Information (PHI), for which use or access is being requested, is included in the protocol summary or a separate data collection document and is necessary for the research.

The use or disclosure of protected health information involves no more than a minimal risk to the privacy of individuals, based on, at least, the presence of the following elements: an adequate plan to protect the identifiers from improper use and disclosure; an adequate plan to destroy the identifiers at the earliest opportunity consistent with conduct of the research, unless there is a health or research justification for retaining the identifiers or such retention is otherwise required by law; and adequate written assurances that the protected health information will not be reused or disclosed to any other person or entity, except as required by law, for authorized oversight of the research study, or for other research for which the use or disclosure of protected health information for which an authorization or opportunity to agree or object is not required by 45 CFR 164.512.

The research could not practicably be conducted without the waiver or alteration.

The research could not practicably be conducted without access to and use of the protected health information.

Please contact the IRB at (215) 707-3390 if you have any questions.

2/11/2021
Date

IRB Program Coordinator

Temple University
Office of the Vice President for Research

Research Integrity & Compliance
Student Faculty Center
3340 N. Broad Street, Suite 304
Philadelphia PA 19140

Institutional Review Board
Phone: (215) 707-3390
Fax: (215) 707-9100
e-mail: irb@temple.edu

Approval for a Project Involving Human Subjects Research that is Approved as Exempt

Date: 11-Feb-2021

Protocol Number:	27839
PI:	SCIOTE, JAMES J.
Review Type:	EXEMPT
Approved On:	11-Feb-2021
Risk:	Minimal risk
Committee:	A1
Sponsor:	NO EXTERNAL SPONSOR
Project Title:	Correlation between Modified Mallampati Tongue Score with Variations in Craniofacial Posture & Morphology in a Lateral Cephalogram

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The IRB approved the protocol 27839.

The study was approved under Exempt review. The IRB determined that the research **does not require a continuing review**, consequently there is not an IRB approval period.

As this research was approved as Exempt, the IRB will not stamp the consent or assent form(s).

Note that all applicable Institutional approvals must also be secured before study implementation. These approvals include, but are not limited to, Medical Radiation Committee (“MRC”); Radiation Safety Committee (“RSC”); Institutional Biosafety Committee ("IBC"); and Temple University Survey Coordinating Committee ("TUSCC"). Please visit these Committees’ websites for further information.

Finally, in conducting this research, you are obligated to submit the following:

- **Modifications - Any changes to the research that may change the Exempt status of this study must be reviewed and approved by the IRB prior to implementation.** Examples of such changes are: including new, sensitive questions to a survey or interview, changing data collection such that de-identified data will now be identifiable, including an intervention in the methods, changing variables to be collected from medical charts, decreasing confidentiality measures, including minors or adults lacking capacity to consent as subjects when previously only adults with capacity to consent were to be enrolled, no longer collecting signed HIPAA Authorization, etc. Please reach out to the IRB Staff with any questions about if a change to the study warrants a Modification.
- **Reportable New Information** - Using the Reportable New Information e-form, report new information items such as those described in HRP-071 Policy - Prompt Reporting Requirements to the IRB **within 5 days**.
- **Closure report** - Using a closure e-form, submit when the study is permanently closed to enrollment; all subjects have completed all protocol related interventions and interactions; collection of private identifiable information is complete; and analysis of private identifiable information is complete.

APPENDIX B: INSTRUCTIONS FOR CEPHALOMETRIC ANALYSIS ON AMIRA SOFTWARE

INSTRUCTIONS FOR CEPHALOMETRIC ANALYSIS ON AMIRA SOFTWARE

(Resting tonicity of skeletal muscles relative to skeletal and soft tissue elements in the oral pharyngeal areas)

1. Open Amira Software
2. **File** → **New Project**
3. **Open Data** → Locate Ceph (.jpg) → Image Read Parameters (*Figure 1*) → **OK**

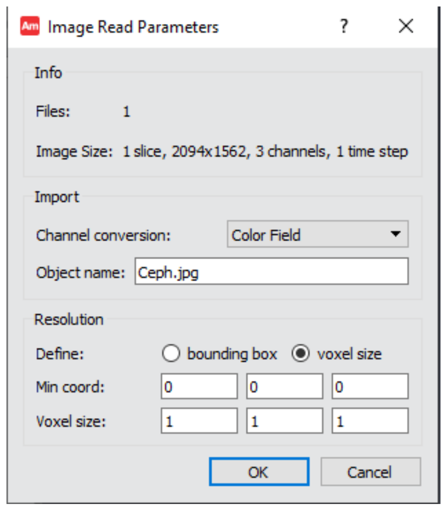

Figure 1

4. To Import Cephalogram to Amira Software
   a. Green Box Ceph.jpg (Click **Grey Arrow >**) → **Favorites** → **Ortho Slice** → **Create** (*Figure 2*)

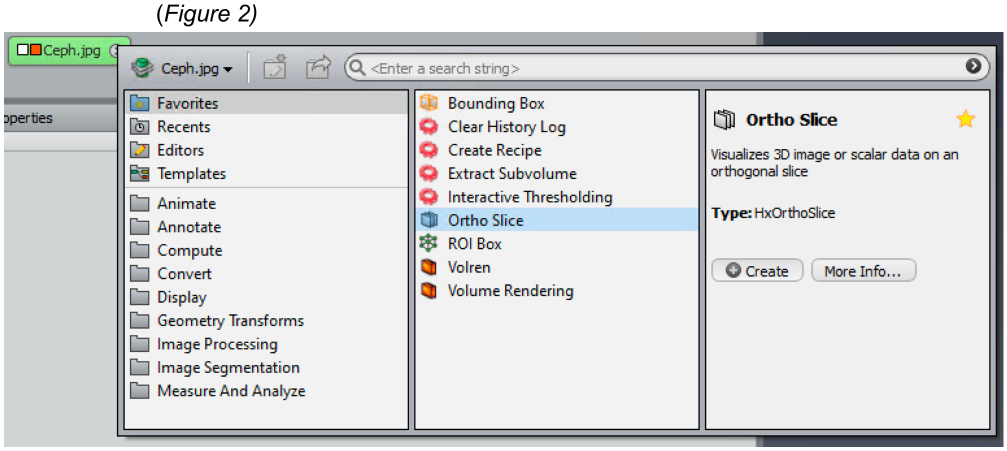

Figure 2

5. To Perform Linear and Angular measurements:
    a. Select **Line** or **Angle** Measurement tool on Toolbar (*Figure 3*) and select points on cephalogram to perform measurements.
    Values inputted into excel data collection sheet.
    *Line Measurement Amira Conversion Factor: 0.12821
    → 5mm = 39 Amira units. Conversion done on excel sheet.
    **Vert Hyoid Neck Measurement (*Figure 4):*
    If RGn-cv3 is above H (value = positive)
    If RGn-cv3 is below H (value = negative)
    If RGn-cv3 intersects H (value = 0)

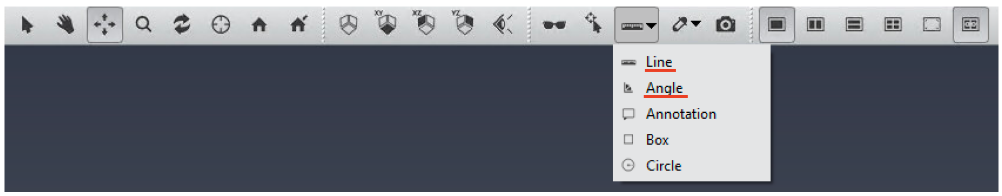

Figure 3

    b. Label Line/Angle under **Title** (*Figure 4)*

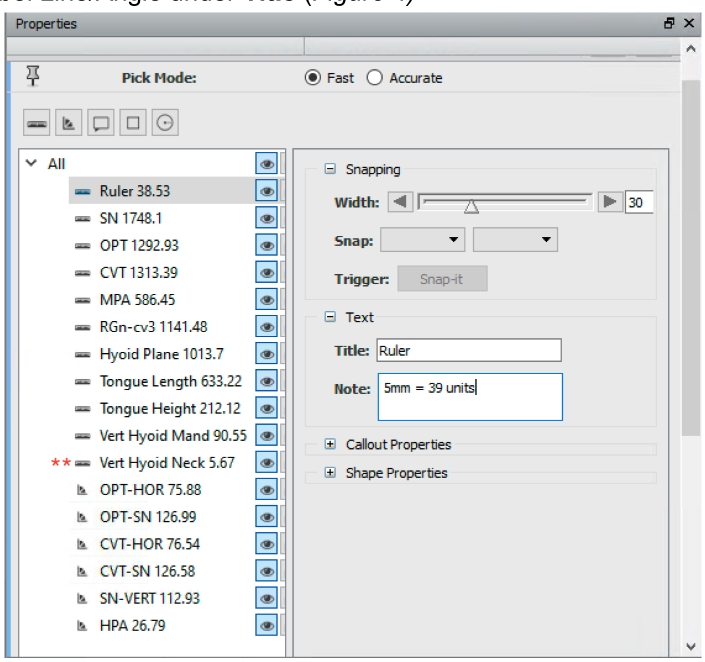

Figure 4

    c. To Remove Line - Right click **Line or Angle** and **Remove**

6. To Save Analyzed Amira Cephalogram
Save project As → Name Project → **Save**

APPENDIX C: SUMMARY OF SUBJECTS & RAW DATA COLLECTION

(Craniofacial Head Posture Measurements)

Subject	Tongue Length (mm)	Tongue Height (mm)	Vert Position of Hyoid to Mand (mm)	Vert Position of Hyoid to Neck (mm)	OPT-HOR (deg)	CVT-HOR (deg)	OPT-SN (deg)	CVT-SN (deg)	SN-VERT (deg)	Hyoid Plane Angle (deg)
1	77.70	28.18	14.39	1.90	82.87	77.12	103.47	107.67	93.70	12.32
4	79.21	30.99	11.87	1.62	91.23	85.20	102.20	107.01	102.14	29.80
5	84.78	32.33	9.17	-1.31	78.01	73.19	114.08	115.89	101.98	10.94
6	77.79	39.13	19.43	3.84	76.21	73.49	115.04	118.61	101.13	22.39
7	71.38	28.85	13.34	3.44	99.61	92.74	94.11	102.82	105.35	31.48
8	59.75	33.66	9.57	-1.34	103.91	98.51	85.43	90.18	98.99	20.87
9	68.86	31.90	6.94	-1.88	85.26	110.08	109.00	110.08	104.03	2.32
11	85.73	32.04	11.15	4.66	90.82	89.08	103.09	105.07	103.53	9.00
12	71.12	29.60	6.73	-1.18	102.98	97.34	86.49	92.66	99.95	12.14
13	72.07	32.77	16.31	7.65	99.72	91.01	93.86	102.73	104.07	20.66
14	79.71	35.41	9.34	-3.66	84.90	79.78	105.16	110.58	100.07	6.43
16	71.60	31.62	12.00	6.51	95.23	91.34	99.22	102.49	102.50	15.08
17	67.26	29.89	4.30	-1.48	92.68	89.35	94.60	97.68	97.55	0.88
18	84.85	36.59	19.44	12.51	84.04	80.54	97.68	101.91	91.95	6.74
19	89.28	29.34	9.00	-0.99	60.50	58.11	122.77	125.21	93.14	4.46
20	86.59	35.21	16.14	8.75	95.72	91.12	99.14	104.58	105.85	9.50
21	78.39	29.02	9.40	-1.47	93.70	92.13	100.76	102.19	104.12	8.24
22	95.79	34.22	8.83	-1.48	79.87	77.43	100.79	103.59	90.74	14.47
23	71.87	37.53	4.72	-3.60	90.94	86.22	91.47	95.57	92.94	17.47
24	78.89	29.29	10.53	-7.33	76.01	71.55	122.11	126.89	109.01	24.30
25	83.50	47.72	22.31	21.09	104.58	101.84	85.47	87.99	100.47	4.48
26	78.66	32.25	6.07	-2.47	95.41	89.09	94.03	101.09	99.57	6.00
27	79.77	38.69	10.02	1.00	92.69	86.70	89.80	94.34	92.68	1.37
28	83.04	36.74	8.43	3.62	84.38	83.53	108.68	109.06	103.82	3.40
29	81.49	25.92	16.28	5.06	79.56	77.88	102.21	104.13	93.27	20.54
30	74.23	26.01	18.50	5.71	67.77	65.39	124.20	127.46	102.09	35.86
31	80.44	30.88	7.64	-7.40	87.49	80.36	97.61	103.78	93.94	17.19

Subject	Tongue Length (mm)	Tongue Height (mm)	Vert Position of Hyoid to Mand (mm)	Vert Position of Hyoid to Neck (mm)	OPT-HOR (deg)	CVT-HOR (deg)	OPT-SN (deg)	CVT-SN (deg)	SN-VERT (deg)	Hyoid Plane Angle (deg)
32	86.54	31.74	13.62	7.97	79.41	80.76	112.20	108.52	99.94	17.60
33	78.26	33.02	14.11	11.74	75.86	73.23	119.54	125.36	106.25	30.86
34	83.57	32.26	18.30	11.16	77.27	76.13	111.30	112.95	97.31	18.62
35	70.34	26.38	9.85	-3.27	74.88	68.11	109.04	116.25	96.02	14.67
36	73.51	27.81	8.18	-6.95	21.05	70.87	115.24	111.41	93.41	21.05
37	79.45	32.15	9.24	4.99	86.33	79.44	100.87	107.39	99.48	12.74
38	80.45	28.09	34.86	23.14	85.19	84.76	96.52	99.20	93.93	27.42
39	81.20	29.48	22.77	5.22	74.28	66.48	116.04	123.16	102.81	39.13
40	72.33	28.98	12.78	0.00	93.22	87.87	101.72	104.99	104.44	24.94
41	79.36	26.42	28.71	14.75	80.60	80.98	101.22	99.61	93.87	37.84
42	75.82	32.49	10.09	1.54	96.82	92.71	93.75	96.89	101.55	14.62
44	79.39	35.66	17.36	10.62	85.96	87.06	98.52	98.33	96.28	27.68
45	65.63	28.00	10.46	8.18	96.73	91.76	87.28	92.98	93.68	22.31
46	73.78	30.92	24.01	20.07	99.46	97.80	82.05	88.21	95.40	25.65
47	69.98	31.19	9.18	6.96	87.78	89.61	99.47	98.24	101.15	24.02
48	75.99	31.58	12.68	6.83	74.55	69.15	118.55	120.75	102.74	8.45
50	81.30	37.16	12.54	4.84	89.61	91.51	106.86	102.01	102.44	11.13
53	72.24	24.66	17.40	2.62	87.40	74.54	116.20	126.01	113.55	25.20
54	79.07	29.24	17.18	11.12	85.53	83.39	102.98	98.58	96.59	20.66
55	79.90	30.45	11.60	0.00	71.35	73.61	131.28	133.01	115.83	19.15
56	70.57	23.38	8.07	2.78	89.95	90.00	90.80	91.14	93.14	26.68
57	91.73	41.34	21.49	11.32	31.40	84.60	113.94	119.15	115.54	21.95
58	76.38	33.06	14.89	7.41	82.52	74.40	99.70	109.55	92.91	27.50
59	85.60	31.62	24.23	12.05	89.38	79.44	102.72	112.89	102.68	38.94
60	83.76	35.79	11.65	0.00	81.68	77.97	107.26	111.38	99.70	16.52
61	86.50	30.53	8.81	7.28	78.35	79.48	105.02	103.30	92.19	9.30
62	86.57	32.27	11.29	-1.58	79.44	75.88	109.77	114.23	100.33	4.11
63	82.81	34.06	18.62	7.56	88.81	83.13	100.70	108.43	101.36	10.84
64	83.81	29.34	15.56	2.27	83.03	77.35	109.92	115.20	104.22	30.09
65	78.56	37.76	7.93	1.93	89.09	85.99	95.93	98.83	95.39	13.14
66	83.36	36.00	15.53	5.07	79.83	77.14	101.42	104.66	92.17	21.53
68	78.55	38.44	14.42	4.29	90.53	88.24	98.60	101.15	92.00	22.65

Subject	Tongue Length (mm)	Tongue Height (mm)	Vert Position of Hyoid to Mand (mm)	Vert Position of Hyoid to Neck (mm)	OPT-HOR (deg)	CVT-HOR (deg)	OPT-SN (deg)	CVT-SN (deg)	SN-VERT (deg)	Hyoid Plane Angle (deg)
69	78.09	30.89	17.54	8.44	87.31	83.97	104.97	108.23	102.77	22.92
70	75.15	33.27	19.33	19.11	69.61	93.87	95.08	96.71	102.06	9.95
71	84.69	42.10	11.19	5.50	86.52	85.06	101.15	100.75	97.56	4.19
72	56.53	37.96	8.42	2.89	83.00	82.64	96.17	97.07	89.10	13.13
73	92.41	28.32	27.87	19.76	72.93	72.29	116.21	116.93	99.71	28.64
75	72.39	27.82	16.72	4.41	80.51	75.90	115.42	118.69	105.88	31.01
77	87.35	31.90	16.04	-1.25	77.24	76.53	115.86	118.01	104.26	29.88
78	93.55	37.09	17.34	4.45	79.14	74.86	106.97	111.49	96.94	26.79
79	72.94	31.62	19.09	4.08	78.49	73.53	115.67	120.67	104.81	13.10
81	62.25	28.43	10.97	4.52	92.05	89.51	91.73	93.38	93.70	27.01
82	83.89	33.51	6.92	11.26	88.95	88.73	96.44	95.98	97.26	15.69
83	92.73	30.39	19.69	10.96	82.19	79.45	108.68	111.35	101.06	27.19
84	79.51	22.06	8.89	-2.56	78.91	70.75	106.98	116.34	98.01	10.34
85	78.20	31.21	12.37	0.00	91.74	87.56	103.13	108.77	105.69	12.82
87	67.82	30.24	8.99	2.14	93.69	89.34	92.65	98.38	97.75	7.07
88	71.88	29.45	13.94	13.94	88.32	87.62	102.14	103.81	100.67	25.08
89	69.48	28.52	12.37	4.45	83.42	78.87	106.71	110.37	98.87	21.22
90	76.23	23.74	1.24	-2.88	84.70	80.34	107.18	110.11	103.18	16.35
91	86.55	32.46	13.09	0.00	88.90	83.40	98.31	103.71	97.41	13.67
92	78.59	27.26	14.51	5.44	93.26	86.24	100.81	108.92	105.16	23.95
93	80.00	31.85	7.04	3.10	92.17	87.15	103.13	107.10	106.18	11.14
95	91.25	30.45	15.98	7.57	80.67	79.10	108.23	109.55	98.74	13.85
96	83.74	33.13	15.23	4.82	91.53	86.60	104.46	108.21	105.58	12.52
97	84.88	34.61	23.95	8.65	80.14	75.26	111.86	116.35	102.31	20.90
98	80.03	35.09	14.33	6.95	81.42	75.96	103.25	109.21	96.37	29.00
99	84.49	34.05	8.75	8.74	94.14	88.79	90.93	95.60	95.85	4.63
100	89.07	29.04	13.62	3.66	72.13	73.04	117.73	117.53	100.93	18.78
101	84.66	31.03	13.31	4.37	87.33	109.98	104.99	109.98	103.97	20.49
102	89.20	36.54	16.77	11.30	85.49	77.31	97.38	105.62	92.88	23.61
103	77.56	28.25	10.57	1.12	98.73	96.05	92.49	93.21	100.60	18.73
105	72.77	34.09	14.49	3.12	89.44	85.56	104.55	108.11	104.57	31.41
106	91.71	29.08	12.90	3.45	86.45	100.54	99.64	100.54	95.85	15.35

Subject	Tongue Length (mm)	Tongue Height (mm)	Vert Position of Hyoid to Mand (mm)	Vert Position of Hyoid to Neck (mm)	OPT-HOR (deg)	CVT-HOR (deg)	OPT-SN (deg)	CVT-SN (deg)	SN-VERT (deg)	Hyoid Plane Angle (deg)
107	74.91	36.43	8.82	2.02	92.74	87.05	92.48	98.55	95.56	18.25
108	78.87	32.11	14.03	3.84	79.46	78.83	114.02	113.10	102.60	25.18
109	92.89	32.66	19.14	3.34	78.47	73.46	119.92	123.11	108.06	35.00
110	74.94	30.02	10.28	0.00	85.04	78.70	104.15	107.88	98.16	24.35
111	78.99	32.86	11.80	-2.37	85.15	78.26	112.14	118.52	107.30	15.47
112	86.24	32.38	16.32	6.68	83.75	79.57	115.92	118.75	110.14	16.93
113	71.01	29.95	5.49	-11.15	92.48	86.82	97.26	102.10	98.70	22.77
114	81.79	41.14	22.09	20.92	88.73	88.17	93.21	94.26	91.75	21.70
116	73.20	23.33	14.11	0.00	72.50	73.74	111.34	109.25	93.15	28.49
117	81.65	28.59	22.24	1.81	84.25	79.76	119,02	122.42	114.29	25.31
119	86.94	28.19	21.04	5.27	81.69	77.25	115.01	119.17	107.30	28.34
120	89.32	29.32	14.36	1.33	68.71	68.62	117.10	117.73	96.40	6.13
121	85.46	29.19	17.83	4.37	82.63	80.63	107.98	110.50	101.32	28.18
122	84.26	36.00	13.15	1.11	84.66	83.75	104.42	105.62	99.83	26.95
123	89.98	36.03	18.90	14.50	92.06	85.51	90.47	97.96	92.56	24.86
124	84.99	36.93	15.11	10.65	81.73	80.15	101.70	103.44	92.97	13.53
125	78.36	41.46	11.26	11.85	91.05	92.59	92.09	90.67	92.78	4.22
126	76.52	34.06	11.44	4.63	111.83	97.65	85.99	100.08	107.86	19.43
127	73.20	35.46	18.57	13.84	93.98	92.55	89.62	91.48	93.08	28.51
128	88.17	28.99	4.70	2.66	74.31	71.46	108.56	111.06	93.17	10.58
129	80.95	34.06	20.84	13.14	84.65	80.46	99.14	103.51	94.11	21.98
130	68.57	35.78	12.36	3.40	102.97	99.63	93.30	97.33	106.92	28.64
131	83.17	31.96	0.00	-6.50	87.86	86.92	98.96	101.16	97.15	14.70
132	91.05	39.60	17.65	11.68	78.22	65.65	109.54	122.82	98.27	15.77
133	72.06	35.58	4.88	-3.90	92.89	97.85	92.89	97.65	105.15	3.14
134	82.63	32.18	13.48	6.94	84.94	83.21	107.74	108.53	103.25	12.91
135	84.18	33.58	10.97	4.77	78.95	77.78	117.43	118.15	106.35	9.17
136	83.46	35.96	22.97	9.41	85.53	83.41	116.17	119.58	112.61	28.32
137	75.60	30.10	11.52	0.00	98.77	91.57	91.93	97.29	100.17	5.43
138	83.04	27.73	21.78	12.02	92.43	86.67	99.59	106.74	103.44	31.10
141	80.74	30.71	10.05	2.19	85.96	85.27	100.93	102.08	96.84	16.08
142	79.37	33.52	20.26	6.86	95.05	87.56	104.86	112.82	110.93	30.43

Subject	Tongue Length (mm)	Tongue Height (mm)	Vert Position of Hyoid to Mand (mm)	Vert Position of Hyoid to Neck (mm)	OPT-HOR (deg)	CVT-HOR (deg)	OPT-SN (deg)	CVT-SN (deg)	SN-VERT (deg)	Hyoid Plane Angle (deg)
143	72.07	26.22	12.91	3.67	85.57	80.42	101.38	106.55	97.76	27.69
144	65.77	26.17	9.12	1.98	108.36	103.98	85.27	90.87	104.73	5.41
146	70.67	32.85	4.29	-1.17	98.67	96.52	92.36	94.86	101.41	15.46
147	80.82	27.82	8.65	4.35	82.99	78.94	104.39	110.12	97.68	3.17
149	69.19	30.22	13.34	-4.22	78.28	78.40	109.34	108.93	97.53	25.04
150	68.13	30.07	10.68	0.00	84.52	82.64	97.99	100.18	92.43	23.79
153	77.79	33.75	19.80	1.32	83.34	76.01	101.78	110.37	95.74	17.41
154	66.91	35.48	7.97	3.29	99.56	97.94	83.28	85.31	91.52	9.05
155	74.38	30.13	5.07	4.75	89.71	89.23	96.09	96.25	95.12	13.73
156	79.66	36.76	7.08	-2.84	83.77	82.29	107.45	109.42	101.99	15.98
157	89.86	37.66	26.29	17.24	91.13	87.24	99.19	103.74	100.97	26.45
158	83.10	42.07	19.55	13.48	98.26	93.53	85.47	90.29	94.08	12.98
160	69.49	32.11	23.50	15.46	89.02	84.73	100.96	105.40	99.95	28.19
161	89.49	33.14	16.26	4.64	83.21	81.33	101.51	103.37	94.96	31.54
162	79.91	34.00	16.84	0.00	73.38	70.64	118.51	121.96	102.58	23.65
163	75.70	36.60	10.02	0.00	100.93	94.37	95.74	100.75	105.25	11.76
164	77.79	32.97	12.00	2.88	87.79	76.42	105.73	117.69	103.75	22.21
165	83.36	28.35	11.31	3.10	93.52	87.21	93.90	98.96	97.83	22.51
166	66.20	29.72	9.81	5.18	99.11	93.61	87.47	93.60	96.55	9.79
167	67.20	25.13	19.34	11.75	110.61	106.59	91.41	94.63	110.72	27.60
168	85.08	30.71	14.44	3.18	81.07	75.64	98.61	103.26	87.92	9.76
169	82.91	37.61	11.49	6.42	81.74	79.86	100.76	103.79	93.36	8.66
171	81.56	39.88	15.90	6.52	95.17	83.39	88.72	100.09	93.63	18.43
172	73.22	33.35	18.18	4.16	94.09	91.75	101.55	104.60	106.64	5.08
173	76.23	31.84	18.59	7.95	82.87	79.53	109.87	113.73	102.77	34.72
174	59.64	31.07	5.24	0.00	94.24	98.51	98.04	95.09	102.72	4.87
175	84.31	35.20	1.86	-2.23	84.29	83.44	109.74	109.70	103.92	6.47
176	82.05	39.33	18.14	3.82	92.18	86.92	96.39	101.59	99.02	28.64
177	80.86	32.83	25.26	0.00	74.02	71.67	107.67	110.60	91.94	24.53
178	73.34	32.20	15.53	1.82	83.92	79.22	102.05	107.10	96.08	15.09
179	82.70	35.25	13.42	7.37	96.16	91.71	95.65	100.17	101.62	19.69
180	66.85	30.41	13.54	-0.99	82.24	76.23	112.28	118.30	104.84	24.45

Subject	Tongue Length (mm)	Tongue Height (mm)	Vert Position of Hyoid to Mand (mm)	Vert Position of Hyoid to Neck (mm)	OPT-HOR (deg)	CVT-HOR (deg)	OPT-SN (deg)	CVT-SN (deg)	SN-VERT (deg)	Hyoid Plane Angle (deg)
181	77.39	33.52	20.29	12.65	91.27	100.44	96.55	87.13	97.52	13.63
183	91.05	40.03	19.87	10.96	82.20	76.93	108.66	112.81	99.90	21.73
184	80.16	35.41	10.25	4.75	85.74	88.88	101.18	99.01	97.86	11.58
185	81.94	27.83	12.23	0.00	91.47	88.65	100.97	104.42	102.62	21.73
186	78.68	29.99	12.08	-2.61	87.31	82.72	99.40	104.00	97.28	9.74
187	94.23	25.12	32.59	22.99	84.14	76.98	98.72	105.78	93.30	24.88
188	74.08	33.86	9.48	-3.65	93.57	88.04	102.32	108.07	105.84	18.85
189	73.68	26.27	14.36	2.06	75.68	73.40	120.40	120.68	105.30	26.30
190	85.07	32.28	16.75	5.49	80.40	74.90	120.56	124.76	110.08	8.71
191	79.38	26.04	22.60	11.81	74.16	72.29	117.11	118.70	100.30	38.33
192	92.53	36.33	24.30	16.00	87.78	79.59	102.07	111.51	101.52	26.89
193	79.08	29.92	15.06	5.26	96.30	94.31	88.83	90.79	94.49	16.06
194	76.86	29.90	18.15	9.05	84.63	83.76	99.77	99.32	93.92	20.63
195	76.45	31.57	9.48	1.90	26.13	86.82	101.33	99.06	96.05	18.52
196	73.67	36.15	18.40	11.48	91.76	98.64	97.60	97.52	105.46	21.68
197	80.07	33.05	4.65	-6.77	95.70	95.23	91.31	92.88	97.08	9.06
199	79.66	36.57	13.97	6.86	87.55	83.02	115.84	119.11	113.71	9.94
200	86.32	33.19	11.70	0.00	94.09	86.75	100.73	107.69	104.11	18.28
201	77.71	32.12	0.00	-2.67	88.86	89.69	104.52	103.80	102.87	3.18
204	80.75	32.55	16.15	0.83	85.75	84.09	108.82	110.73	104.14	3.87
205	85.68	27.58	18.51	11.64	80.05	75.79	104.23	107.98	93.94	17.41
206	67.18	33.78	5.03	-1.89	91.78	90.58	94.38	95.70	95.42	11.31
207	74.34	35.07	12.54	2.77	95.84	86.71	94.46	102.49	100.51	24.25
208	77.82	29.77	11.43	2.27	88.73	85.70	100.89	103.43	98.74	22.17
209	79.15	30.03	24.69	11.95	91.67	83.62	103.11	111.04	103.21	36.50
210	80.82	30.21	20.92	7.48	72.35	71.15	113.96	116.75	97.98	30.76
211	73.29	35.72	15.92	4.75	98.91	94.03	88.75	93.76	98.11	12.35
212	68.42	27.95	8.55	0.60	90.98	85.25	100.31	104.56	101.19	22.48
213	70.48	30.16	10.77	2.88	81.98	82.27	106.88	106.67	99.27	16.20
214	70.34	36.79	12.96	1.64	100.48	95.88	88.80	95.25	101.49	12.50
215	82.74	29.84	15.29	3.65	87.37	86.03	106.64	108.25	104.15	27.91
216	64.70	33.56	5.03	-5.33	86.32	85.43	104.92	106.53	101.10	9.34

Subject	Tongue Length (mm)	Tongue Height (mm)	Vert Position of Hyoid to Mand (mm)	Vert Position of Hyoid to Neck (mm)	OPT-HOR (deg)	CVT-HOR (deg)	OPT-SN (deg)	CVT-SN (deg)	SN-VERT (deg)	Hyoid Plane Angle (deg)
217	82.24	36.36	18.39	6.50	101.22	89.99	91.68	104.18	103.06	33.24
218	78.10	37.48	10.39	1.71	81.14	76.10	102.02	107.88	93.97	27.20
219	79.94	34.85	11.91	2.14	81.84	79.77	111.89	114.06	104.82	14.94
220	72.70	31.79	13.04	5.05	94.65	90.06	95.98	99.98	101.22	9.62
221	82.09	39.29	17.51	3.71	86.11	81.24	113.98	118.01	109.85	12.95
222	73.25	33.43	13.17	4.95	100.06	96.15	96.04	101.33	108.09	4.79
223	72.88	39.27	10.70	5.94	102.35	97.58	90.63	95.17	102.53	6.01
225	81.95	46.67	20.54	17.05	93.71	91.15	96.60	98.67	99.96	12.04
226	63.81	37.71	14.24	1.49	94.04	90.75	96.21	98.52	99.62	17.01
227	81.19	27.20	11.61	0.00	75.88	126.58	126.99	126.58	112.93	26.79
229	80.18	39.33	23.36	10.89	92.22	87.24	101.16	106.74	103.77	22.72
230	71.81	31.99	7.64	0.00	99.04	94.45	87.17	91.09	97.36	3.93
231	79.50	29.14	19.07	15.76	88.91	86.89	99.50	100.16	97.18	10.70

APPENDIX D: SUMMARY OF SUBJECTS & RAW DATA COLLECTION

(Craniofacial Morphology Measurements)

Subject	ANB (deg)	SNA (deg)	SNB (deg)	Wits (mm)	A-N:Perp (mm)	Pog-N:Perp (mm)	Vertical Ratio
1	2.4	78.6	76.2	-7.3	1.9	0.4	0.56
4	4.7	84.6	79.9	-2.5	8.4	5.8	0.55
5	3.5	76.9	73.4	-4.5	0.3	-7.1	0.55
6	5.7	88	82.4	-1.3	6	2.8	0.56
7	1.8	82.9	81.2	-1.6	5.4	7.8	0.61
8	2.9	79.9	77.1	5.9	-0.5	-3.9	0.55
9	5.7	78.5	72.8	-5	0.8	-7.4	0.56
11	8.6	89.2	80.6	0.2	12.6	8	0.59
12	2.9	82.4	79.4	-2.3	2.4	-1.7	0.56
13	5.3	82	76.7	0.7	4.8	0.4	0.57
14	1.9	81.8	79.8	-5.5	0.6	-1	0.60
16	5.7	90.9	85.2	-2.1	3.9	-0.9	0.67
17	4	88.5	84.5	-4.2	4.8	4.3	0.62
18	4.9	94.2	89.3	-4.6	5.1	1.2	0.60
19	6.4	89.3	82.9	-1.2	6	-0.6	0.59
20	1.9	82.2	80.2	-2.5	3.4	4.9	0.65
21	3.8	86.4	82.6	-5.3	6	3.7	0.64
22	3.3	90.6	87.3	-3.6	4.2	-1	0.58
23	3.8	88	84.2	-0.6	2.6	-2.5	0.63
24	9.4	82.1	72.7	-0.6	5.4	-6.8	0.57
25	1.8	86.2	84.4	-3.9	0.7	-2.4	0.60
26	3.4	86.6	83.2	-6.3	5.9	6.9	0.57
27	2.8	88.8	86	-9.7	2.5	0.2	0.58
28	1.8	84.3	82.5	-6.4	1	-4.3	0.59
29	12.5	91.1	78.6	6.8	10.2	-4.8	0.48
30	3.5	80.5	77	-1.9	2.2	-0.8	0.56
31	3.4	91.5	88	-3.4	5.7	-0.1	0.54
32	5.6	84.3	78.7	-2.7	6.6	1.9	0.62
33	-3.3	75.4	78.7	-11.9	3.4	13	0.60
34	8.2	91.1	82.9	2.7	7.3	-3.5	0.60
35	6.1	88.8	82.7	-2.2	3.5	-3.6	0.55

Subject	ANB (deg)	SNA (deg)	SNB (deg)	Wits (mm)	A-N:Perp (mm)	Pog-N:Perp (mm)	Vertical Ratio
36	1.8	83.3	81.5	-3.2	-0.2	-3.1	0.63
37	-1	81.4	82.4	-4.7	0.2	2.8	0.64
38	4.4	88.5	84.1	2.6	2.8	2.3	0.69
39	7.9	78.9	71	-2.1	1.8	-12.6	0.52
40	0.5	77.7	77.2	-3.2	-2.4	-2.7	0.54
41	5	91.1	86.1	-2.7	2.6	-3.4	0.58
42	5	89.7	84.7	-1.8	10	9.3	0.59
44	12	88.9	76.9	8.9	5.4	-12.3	0.53
45	4	82.3	78.2	-0.8	2.3	-2	0.56
46	6.9	90	83.1	-2.5	5.5	-0.3	0.62
47	3.8	82	78.2	-3.1	1.1	-3.8	0.56
48	4.4	78.4	74	-0.5	3.6	0.7	0.56
50	4.1	77.1	73	1.6	5.6	2.6	0.49
53	3.9	79.5	75.7	-0.3	8	10.3	0.52
54	5.5	88.3	82.8	4.9	5.9	0.4	0.58
55	8.1	72.8	64.7	9.3	-2.6	-19.8	0.54
56	6.1	85.8	79.8	-5.3	1.3	-8.1	0.59
57	1.8	82.5	80.7	-14.7	9.1	11.9	0.52
58	5.3	88	82.7	-5.2	4.2	-2.4	0.58
59	6.8	78.9	72.1	5	2.4	-9.1	0.58
60	5	87.3	82.3	-4.6	10.3	7	0.60
61	4.7	84.9	80.3	1.9	5.1	-0.2	0.62
62	2.4	81.9	79.5	-2.5	3.8	2.9	0.53
63	1.3	84.4	83.1	-5.5	4.4	5.8	0.59
64	8.7	91.5	82.8	-2.4	10.5	0.7	0.55
65	4.7	87.1	82.4	-5.1	4	-1.8	0.56
66	8.4	93.1	84.8	-4.2	8.1	0.3	0.59
68	0.4	84.5	84	-3.6	3	7.3	0.61
69	0.9	76.1	75.2	-9.2	2.6	5.6	0.55
70	3.6	81.3	77.7	-5.6	3.3	1	0.52
71	6.8	90.2	83.4	-6.3	11.2	7.8	0.54
72	0.2	91.1	90.9	-6.9	6.4	12.3	0.67
73	9.2	87.5	78.3	-0.2	7.7	-1.7	0.56
75	3.2	77.7	74.4	-5.7	3.5	-0.3	0.56
77	6.9	85.2	78.3	6.1	4.9	-2.4	0.53

Subject	ANB (deg)	SNA (deg)	SNB (deg)	Wits (mm)	A-N:Perp (mm)	Pog-N:Perp (mm)	Vertical Ratio
78	3.8	84.6	80.8	0.8	3.2	-0.5	0.52
79	4.5	74.2	69.7	-1.7	-0.5	-7.8	0.52
81	5.1	90	84.9	-1	1.8	-5	0.60
82	3	83.1	80.1	-8.8	1.6	-4.4	0.57
83	3.9	83.7	79.8	-0.3	3	-2.1	0.61
84	-0.2	84.6	84.8	-3.4	4.4	9.1	0.06
85	4.5	77	72.5	4.6	6.5	4.7	0.54
87	4.2	88	83.8	-5.4	5.1	1.9	0.58
88	5.2	91.4	86.3	-4.7	7.4	1.9	0.57
89	4.1	83.9	79.7	-3.3	4.7	5.7	0.59
90	5.7	87.5	81.8	-0.1	8.4	9.8	0.62
91	4	93.2	89.2	-8.6	6.4	4.9	0.56
92	5	82.8	77.9	-4.2	7.5	5	0.57
93	7.3	86.3	79	-3.8	6.8	-1	0.58
95	5.7	85.1	79.4	-7.3	6.6	1.4	0.55
96	6.6	84.8	78.2	-1.2	7.7	1.8	0.54
97	2	81	79	-16.2	0.8	-2.6	0.45
98	4.6	85.3	80.6	0	-1.1	-9.5	0.61
99	8.7	89.9	81.2	5.2	7.7	-3	0.63
100	4.8	85.8	81	0.9	8.9	5.1	0.54
101	-0.3	84.1	84.4	-11.4	7.3	15.4	0.63
102	5.3	83.5	78.2	0.5	-1.7	-15.7	0.57
103	2.6	84.7	82.1	0	4.5	6.5	0.54
105	4.9	83.1	78.3	-1	5.5	0	0.55
106	5.3	90.3	85	-2.1	3.9	-1	0.62
107	5.9	89	83.1	1.7	1.8	-6.1	0.60
108	10	94.6	84.5	4.1	11.9	5.7	0.58
109	-1.6	84.1	85.8	-7.8	1.2	6.3	0.59
110	0.8	81	80.2	-3.7	-1.5	-3.5	0.58
111	0.6	78.9	78.3	-7.1	2.9	6.3	0.57
112	1.2	76.2	75	-2.5	1.3	-1.5	0.54
113	-4.9	85.5	87.4	-6.2	0.5	5.9	0.67
114	6.6	92.3	85.7	3.8	3.7	-4.2	0.65
116	5.2	92.5	87.3	-4	5.6	2.4	0.57
117	3.8	81.3	77.5	0.5	2	-2.6	0.57

Subject	ANB (deg)	SNA (deg)	SNB (deg)	Wits (mm)	A-N:Perp (mm)	Pog-N:Perp (mm)	Vertical Ratio
119	2.9	88.4	85.5	-4	6.3	6.5	0.56
120	4.1	80	75.9	-3.6	-0.2	-15	0.56
121	4.9	86.1	81.3	-4.5	7.7	6.9	0.55
122	5.7	86.8	81.1	-3.3	6.7	2.4	0.60
123	8.3	93.4	85.1	4.1	9.2	3.9	0.61
124	5.9	87.3	81.4	-1.2	8.2	4.3	0.56
125	-2.3	89.1	91.5	-8.8	5	14.1	0.76
126	1.8	82.9	81.1	-0.1	6.6	10.8	0.69
127	4.7	85.2	80.5	-1	3.7	0	0.60
128	6.8	84.5	77.7	-1	4.2	-6.7	0.59
129	5.5	83.7	78.2	5.9	-0.5	-10.1	0.66
130	2.5	81.1	78.7	-5.8	6.5	7.8	0.59
131	8.4	89.2	80.8	7.8	5.8	-4.9	0.61
132	2.4	85.1	82.8	-1.8	0.7	-7	0.59
133	-0.7	84.8	85.5	-3.9	6.2	13.8	0.62
134	5.1	88	82.9	-5	6.9	3.3	0.66
135	4.7	82.6	77.8	0.5	0.5	-9.5	0.55
136	9.3	80.6	71.3	2.8	7.2	-3.5	0.56
137	4.4	91.9	87.5	-3	9.2	13.3	0.59
138	7.4	85.9	78.5	-1.5	6.9	0.6	0.57
141	2.9	87.4	84.5	-5.4	5.5	2.5	0.57
142	5.6	81.2	75.6	1.1	6.1	2.1	0.54
143	5.8	86.8	81	-0.9	1.5	-8.3	0.55
144	-0.1	78.9	79.1	-0.3	0	-1.6	0.52
146	2.6	83.9	81.3	-4	5.9	8.4	0.54
147	5.3	90.4	85.1	-4	5.1	-3.1	0.51
149	-1.4	83.7	85.1	-6.7	0.9	4.6	0.61
150	3.8	85.2	81.4	-3.3	0.5	-5.9	0.61
153	-2.4	81.6	84	-7.7	-0.7	5.5	0.64
154	5.8	89.5	83.8	0.8	3.1	-3.6	0.61
155	5.8	86.8	81	-0.9	1.5	-8.3	0.55
156	5.8	85.8	80	-0.1	5.7	0.5	0.59
157	1	77.5	76.4	-1.3	-2.4	-3.8	0.62
158	-1.1	90.6	91.8	-8.3	6.5	14.8	0.63
160	8.4	81.9	73.5	5.6	2.1	-8.1	0.57

Subject	ANB (deg)	SNA (deg)	SNB (deg)	Wits (mm)	A-N:Perp (mm)	Pog-N:Perp (mm)	Vertical Ratio
161	7.6	93.9	86.3	-5.7	7.6	-0.9	0.63
162	3.2	82.1	78.9	-3.4	3.3	0.2	0.52
163	5.5	83.4	77.9	-1.9	5.1	-1	0.54
164	4.5	77.7	73.3	4.5	0.8	-8.7	0.57
165	2.8	86.3	83.4	0.2	3.7	3.7	0.66
166	2.4	83	80.6	-6.4	2.5	1.6	0.58
167	5.5	79.4	73.8	-2.5	-3.9	-18.1	0.47
168	0.6	90.1	89.5	-7.6	0.4	1.5	0.65
169	5.4	85.2	79.8	0.6	2.6	-8.8	0.60
171	-3	86.5	89.5	-10	0.8	10.5	0.72
172	-1.3	77.3	78.5	-0.3	-2.3	0.6	0.59
173	2.5	78.3	75.9	-1.5	1.7	-0.2	0.58
174	5.1	80.2	75.2	-2.2	1.2	-5.7	0.53
175	5.9	83.9	77.9	-7.5	5.8	-4.4	0.60
176	3.4	89.6	86.2	-3.4	6.9	10	0.63
177	0.1	82.6	82.6	-5.5	1.7	6.6	0.57
178	0.9	81.8	80.9	-5.7	0.4	0.3	0.53
179	3.6	89	85.4	-4.1	10.2	10.7	0.60
180	5.8	80.6	74.9	-3	6.6	3.1	0.49
181	3.1	79.9	76.8	-3.7	-3.2	-10.2	0.56
183	5.8	86	80.3	-0.2	4.7	-0.6	0.64
184	2.9	84.5	81.7	-2.8	6.1	6.7	0.56
185	4.6	90.4	85.8	0.5	4.6	-0.8	0.62
186	7	87.1	80.1	-1.9	6.5	1	0.60
187	-3.9	85.4	89.3	-14.3	1.2	9.8	0.58
188	8.4	79.3	70.9	5.6	6.2	-3.7	0.51
189	2	74.8	72.9	-6.9	-0.9	-6.3	0.50
190	13.4	84.6	71.2	15.8	10.1	-4.8	0.53
191	6.9	83.2	76.3	0	5.6	-2.6	0.58
192	6.4	89	82.6	-3.3	8	7.2	0.62
193	1.4	91	89.6	-4.2	6.2	7.9	0.64
194	4.8	85.7	80.9	-3.4	2.8	-2.8	0.57
195	4.4	83.3	78.8	-4.3	2.9	-3.3	0.57
196	5.7	86.7	81	-1.6	5.8	3.4	0.55
197	3.7	90.2	86.5	-4.8	7.4	6.3	0.57

Subject	ANB (deg)	SNA (deg)	SNB (deg)	Wits (mm)	A-N:Perp (mm)	Pog-N:Perp (mm)	Vertical Ratio
199	8.7	74.7	66	7.9	4.8	-7.6	0.50
200	1.6	85.2	83.6	-2.4	4.2	6.6	0.65
201	-0.1	81.7	81.7	-5.3	3.1	6.3	0.60
204	3.5	80.9	77.5	-1.6	1.1	-5	0.48
205	6.9	83.2	76.4	-2.1	1.9	-9.9	0.58
206	5.3	83.4	78.1	3.5	0	-8.7	0.59
207	4.5	86.3	81.9	-5.6	4.7	-0.2	0.55
208	9.1	82.6	73.5	8.5	-0.7	-15.7	0.56
209	10.6	86.1	75.5	-0.7	6.9	-6.1	0.55
210	8.3	85.4	77.1	-1.5	2.9	-10.7	0.56
211	1.6	84.2	82.6	-3.3	0.7	0.2	0.60
212	3.7	82.3	78.6	-1	1	-3	0.60
213	4	84.9	80.9	-4.4	2.4	-2.7	0.54
214	1.2	82.2	81	-3.9	0	-1.5	0.61
215	5	80.6	75.6	-3.4	2.9	-3.5	0.51
216	7.2	85.3	78.1	8.8	5.5	-2.2	0.58
217	4	85.7	81.7	-4.3	6.5	3.2	0.53
218	2.4	84.6	82.2	-9.2	0	-3.4	0.59
219	1.8	81.4	79.6	-7.9	3.5	2.3	0.55
220	2.7	83.2	80.5	-5.2	2.9	1.2	0.59
221	3.7	83.4	79.7	-1.8	4.1	2.6	0.58
222	0.7	76.3	75.6	-1.8	0.9	1.8	0.52
223	4.1	85.7	81.6	-1.7	5.5	2.6	0.56
225	1.5	84.7	83.2	-9.4	3.8	2.9	0.59
226	-3.2	79.9	83.1	-4.4	-0.8	9.2	0.63
227	6.7	83.6	76.8	-0.7	4	-7.2	0.50
229	7.5	84.2	76.7	2.3	5.8	-2.8	0.53
230	7.3	88.8	81.5	-2.5	3.1	-8.7	0.53
231	10.8	93	82.2	3.5	9.8	1.6	0.63

APPENDIX E: SUMMARY OF SUBJECTS & RAW DATA COLLECTION

(Modified Mallampati Tongue Scores, Gender, Age, Race & Ethnicity)

Subject	Age	Race/Ethnicity	Gender	Mallampati
1	16	Hispanic	F	III
4	13	African American	F	I
5	18	African American	F	II
6	12	African American	F	II
7	14	Hispanic	F	III
8	12	Hispanic	F	III
9	25	Hispanic	F	IV
11	17	African American	F	II
12	16	Hispanic	F	II
13	12	Hispanic	F	III
14	16	Hispanic	F	III
16	16	African American	F	II
17	16	Hispanic	F	I
18	14	African American	M	III
19	17	African American	M	II
20	19	African American	M	IV
21	15	African American	F	IV
22	16	African American	M	I
23	15	African American	F	II
24	13	African American	F	IV
25	16	African American	M	IV
26	27	African American	F	I
27	23	Hispanic	M	II
28	21	Caucasian	F	II
29	16	Hispanic	F	IV
30	11	Hispanic	F	I
31	18	African American	F	I
32	16	Hispanic	F	I
33	15	African American	F	II
34	21	Hispanic	M	IV
35	14	African American	F	IV
36	14	African American	F	II

Subject	Age	Race/Ethnicity	Gender	Mallampati
37	13	Asian	F	I
38	61	Caucasian	M	IV
39	17	Hispanic	F	II
40	20	Caucasian	F	II
41	12	Hispanic	M	III
42	16	Hispanic	M	II
44	19	African American	F	III
45	13	Hispanic	F	III
46	30	Hispanic	M	II
47	10	African American	F	III
48	13	Hispanic	M	IV
50	14	African American	F	III
53	14	Hispanic	F	II
54	14	Hispanic	M	II
55	73	Caucasian	F	IV
56	11	African American	M	II
57	55	African American	F	III
58	13	African American	F	II
59	14	Hispanic	F	II
60	18	African American	F	II
61	33	Hispanic	M	III
62	18	African American	F	I
63	19	Hispanic	F	I
64	14	African American	F	II
65	29	African American	F	I
66	13	African American	M	IV
68	46	Caucasian	F	IV
69	11	African American	F	III
70	13	Caucasian	M	IV
71	18	African American	F	I
72	13	Hispanic	F	III
73	30	African American	F	III
75	23	Asian	F	IV
77	33	African American	F	II
78	20	African American	F	II
79	23	Caucasian	F	III

Subject	Age	Race/Ethnicity	Gender	Mallampati
81	9	Hispanic	M	IV
82	14	African American	M	IV
83	14	African American	M	III
84	17	Caucasian	F	III
85	22	Hispanic	F	IV
87	13	Hispanic	M	I
88	7	African American	F	II
89	14	Hispanic	F	II
90	11	African American	F	IV
91	15	African American	F	III
92	15	African American	F	IV
93	16	African American	F	III
95	48	African American	F	III
96	45	African American	F	III
97	14	African American	F	III
98	12	African American	F	III
99	26	African American	F	IV
100	20	African American	F	I
101	18	African American	F	II
102	18	Hispanic	M	II
103	18	African American	F	II
105	15	Hispanic	F	III
106	33	African American	F	IV
107	14	Hispanic	F	I
108	10	African American	F	III
109	13	African American	F	II
110	12	Hispanic	F	III
111	18	Hispanic	F	I
112	15	African American	F	III
113	23	Caucasian	F	I
114	30	African American	M	II
116	9	African American	F	III
117	24	African American	M	III
119	21	African American	F	IV
120	16	African American	M	II
121	49	African American	F	IV

Subject	Age	Race/Ethnicity	Gender	Mallampati
122	21	African American	F	III
123	14	African American	M	III
124	16	African American	F	II
125	43	African American	M	IV
126	13	Caucasian	F	II
127	12	African American	M	IV
128	16	African American	F	IV
129	20	Hispanic	M	III
130	12	Hispanic	F	III
131	37	African American	M	II
132	68	African American	M	I
133	21	Asian	F	I
134	14	African American	M	II
135	28	African American	M	II
136	18	African American	M	IV
137	16	African American	F	II
138	16	Hispanic	F	III
141	18	Hispanic	F	II
142	18	Hispanic	F	III
143	11	African American	M	IV
144	8	African American	F	IV
146	19	Hispanic	F	II
147	16	African American	F	III
149	12	Hispanic	F	III
150	12	Hispanic	M	II
153	19	Hispanic	F	I
154	14	African American	M	III
155	12	Hispanic	F	I
156	27	Caucasian	F	I
157	29	Caucasian	M	III
158	30	Caucasian	M	II
160	12	Hispanic	F	III
161	16	African American	F	III
162	15	African American	F	II
163	15	Hispanic	F	III
164	19	Hispanic	M	IV

Subject	Age	Race/Ethnicity	Gender	Mallampati
165	17	Hispanic	F	III
166	12	Hispanic	F	II
167	14	Hispanic	M	III
168	14	African American	F	I
169	45	African American	M	IV
171	24	Caucasian	M	II
172	55	Caucasian	F	II
173	18	African American	F	III
174	11	Hispanic	M	IV
175	18	African American	M	IV
176	16	Hispanic	M	III
177	13	Caucasian	F	III
178	14	Hispanic	F	II
179	13	African American	F	III
180	12	Hispanic	F	III
181	25	Caucasian	M	III
183	26	African American	M	III
184	14	African American	M	IV
185	17	Hispanic	F	IV
186	18	Hispanic	F	III
187	17	African American	F	III
188	13	Hispanic	F	III
189	19	Hispanic	F	I
190	18	Hispanic	F	IV
191	9	African American	F	I
192	16	Hispanic	M	I
193	14	African American	F	I
194	11	Hispanic	F	IV
195	11	African American	F	II
196	12	African American	F	III
197	20	African American	F	III
199	54	African American	F	III
200	16	African American	F	II
201	18	African American	F	II
204	20	African American	F	I
205	16	African American	F	III

Subject	Age	Race/Ethnicity	Gender	Mallampati
206	14	Hispanic	M	II
207	12	African American	F	I
208	17	Hispanic	F	III
209	21	African American	F	III
210	12	Hispanic	F	II
211	13	Hispanic	M	II
212	16	Hispanic	F	III
213	12	African American	F	III
214	34	African American	F	III
215	16	African American	F	IV
216	25	Hispanic	F	I
217	17	African American	F	II
218	14	African American	F	II
219	21	Hispanic	F	III
220	19	Hispanic	F	IV
221	48	African American	F	III
222	29	Hispanic	F	II
223	23	Hispanic	M	II
225	33	African American	M	II
226	30	Hispanic	F	I
227	21	African American	F	I
229	38	Hispanic	F	III
230	10	African American	F	II
231	12	African American	M	IV